MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LXIX. MAY 14, 1909. No. 7

SIR DAVID GILL, K.C.B., F.R.S., PRESIDENT, in the Chair.

George Bruford, Tolland House, Shoot-up-Hill, Cricklewood, N.W.;

Reinold John Jauget, Captain, Mercantile Marine, 53 Chatsworth Street, Sunderland; and

James Hopwood Jeans, M.A., F.R.S., formerly Fellow of Trinity College, Cambridge, Professor of Applied Mathematics, Princeton University, New Jersey, U.S.A.,

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended:—

Charles Edward Adams, M.Sc., A.I.A. (Lond.), Chief Computer, Survey Office, and Secretary, Surveyors' Board, Wellington, New Zealand (proposed by James McKerrow);

Rev. David Ernest Llewellyn-Jones, The Vicarage, Maindee, Newport, Monmouthshire (proposed by Major-Gen. H. H. Lee);

Percy Mayow Ryves, Farmer, 41 Miguel Servet, Zaragoza, Spain (proposed by the Rev. D. Higham Sparling);

Rev. Frederick William Walker, Vicar of Ellerslie-cum-Epson, Auckland, New Zealand (proposed by J. T. Stevenson); and

Hugh Williams, Lieut. R.N.R., Senior Assistant Marine Surveyor and Water Bailiff, Mersey Docks and Harbour Board, Halwyn, Cecil Road, Prenton, Birkenhead (proposed by William J. S. Lockyer).

Ninety-three presents were announced as having been received since the last meeting, including, amongst others:—

Publications of the Astrophysical Laboratory, Groningen, No. 20; J. C. Kapteyn and W. De Sitter, Parallaxes of 3650 stars, presented by the Laboratory; A. S. D. and E. W. Maunder, The Heavens and their Story, presented by the authors; Oxford University Observatory, Astrographic Catalogue, vol. vi., presented by the Observatory; Australian Meteorology, by Dr. W. J. S. Lockyer, presented by the Solar Physics Committee.

Astrographic Chart; 36 charts, presented by the Royal Observatory, Greenwich; Photographs of the 60-inch reflector of the Mount Wilson Observatory (6 prints), presented by Dr. G. W. Ritchey; Drawing of the lunar crater Archimedes, presented by the Rev. F. B. Allison.

Solar Parallax Papers. No. 7.

The General Solution from the Photographic Right Ascensions of Eros, at the Opposition of 1900. By Arthur R. Hinks, M.A.

§ 1. Earlier papers of this series have dealt with the construction of the standard photographic catalogue of stars (*M.N.*, 1906 June, Nov., 1907 Dec.). This catalogue is now complete, with the exception that it may be possible to incorporate the Algiers results before publication. It contains about 6000 star places; and it serves as the standard to which I have reduced all the photographic and micrometric observations of Eros.

§ 2. *The Published Photographic Observations.*—These are found in Paris Circulars 10–12; they are given in a form which is apparently uniform, but is in reality not quite so. It may be convenient to mention the exceptional cases.

The epochs are in general the mean epochs of observation. But in the case of Bordeaux they have been antedated by the aberration time.

The positions of the planet are in general geocentric. But in the cases of Bordeaux, Northfield, and Toulouse the reductions to the Earth's centre have not been applied.

The positions are in general reduced to apparent place. But in the case of Toulouse the whole effect of the aberration of light has been accidentally omitted from the published positions.

The quantities in the columns headed "parallax" are the *corrections*, which have in most cases been already applied to the quantities in the preceding columns.

The quantities (O – C) are from comparison with the ephemeris of Circular 9.

The positions of the planet are referred to a number of star systems differing slightly from one another. In most cases they have been reduced to standard by the process described in § 4.

§ 3. *The Unpublished Photographic Observations.*—The principal unpublished series is that made with the Crossley reflector of the Lick Observatory, of which a brief discussion has been published within the last few weeks (*L. O. Bulletin* 150).

The measurable field of the Crossley reflector is small—about 24′ in diameter—and the choice of comparison stars consequently restricted. It was of great importance that this fine series should be reduced with well determined stars. I ventured, therefore, to propose to Professor Campbell and Professor Perrine that I should send them charts showing the stars whose places I should eventually be able to supply from the standard catalogue, and that they should select the stars for measurement from these charts. They agreed to do so; and in due course I was able to send them good places of the greater part of the stars which they had used. In a few cases bad weather in Europe had so interfered with observation that the star places were rather weak; and occasionally they have been supplemented from Lick photographs.

Correspondence with Professor Perrine revealed a difference of opinion as to the principle upon which the stars should be selected. The motion of Eros during one night was sufficient to carry the planet half-way across the field of the Crossley reflector. If, then, the same stars were used evening and morning, they could not be symmetrically placed on the plate, which was always centred upon the planet, and the planet would be displaced evening and morning towards opposite edges of the group. If, on the other hand, the comparison stars are chosen to be symmetrical about the planet, different stars must be used evening and morning, and errors in the assumed places of the stars will enter into the parallax determination.

Professor Perrine preferred the first plan. I thought that the second gave a better chance of eliminating systematic error, though at the expense of introducing accidental. So Professor Perrine very kindly undertook that the measures and reductions should be made in both ways.

The second unpublished series consists of the greater part of the Cambridge observations, of which a small part only had been reduced and published in Circular 12. The measurement of the rest of the plates had been delayed until it was possible to select stars from the standard catalogue, on the completion of which the plates were measured and reduced to this system.

We may expect, then, that the Lick and Cambridge series will be in perfect accord with the standard system.

§ 4. *Reduction to Standard.*—The remaining series must, where necessary, be reduced to the standard system.

To effect this without the labour of complete re-reduction, I have adopted the device mentioned in *S.P.P.* No. 6 (*M.N.*, 1907 Dec., p. 96). The programme of M. Loewy provided for the measurement of all stars within the 20′ square centred on the planet, and the separate publication for each plate of the concluded star places. When it was first proposed, this plan seemed

extravagant; but it has proved to be of the greatest value. For among the stars of the square one can generally find ten or a dozen whose places are given in the standard catalogue; and we can compare the positions derived from the individual plate with the catalogue positions. If anything abnormal has happened to the plate, either in making or in reduction, the effect upon the mean of the group of stars distributed over this small square is approximately the same as the effect upon the planet situated at its centre. And so if we apply, as a correction to the place of the planet, the mean of the differences "standard catalogue minus stars of the square," it seems that we should get rid, in a very simple manner, of all discordances of a systematic nature.

This reduction has been applied to the results from Bordeaux, Helsingfors, Paris, Toulouse, and San Fernando. I have not been able to apply it to the results from Minneapolis, Northfield, Pulkowa, and Upsala, because these observatories have not published the stars of the square separately for each plate. In these cases we must rely on general tests for absence of systematic error.

The two series of Greenwich plates are reduced to a system of comparison stars determined at Greenwich, but based upon the same fundamental system (Loewy's) as is the standard catalogue. These stars are included in fields of about 25′ radius; they are therefore closer than the *repère* stars, but not so close as the stars of the square. Many of them are included in my catalogue, and the two systems are in excellent agreement. It seems to me that there can be no doubt that the Greenwich results are practically homogeneous with those reduced directly to my system.

The Oxford results, reduced by me at Cambridge, are referred to my standard system. The same has already been said of the Lick and Cambridge results.

The reduction of the whole material to one standard star system is thus practically complete.

§ 5. *Correction for Refraction.*—In a determination of parallax by the diurnal method, the terms of the second order in the refraction are of great importance, since they change sign with the parallax.

The results from Bordeaux, Cambridge, Greenwich, Oxford, and Pulkowa have been corrected for the second order terms. The field of the Crossley reflector is so small that these terms are insignificant. In the Minneapolis and Northfield plates the field is also comparatively small and the correction hardly sensible; it has apparently not been applied in the reductions. In the remaining series the correction has been omitted, except in one, where it has been computed from an inapplicable formula. It is not permissible to neglect this correction altogether. But fortunately the reduction to standard, explained in § 4, will automatically, and almost completely, effect the necessary correction. I have therefore not computed it separately.

§ 6. *The Aberration of Light.*—The effects of aberration have

been brought to the notice of the Society so recently that it is unnecessary to do more than refer to them very briefly here.

The mean places of the stars, to which the plate is reduced, contain the eccentricity term of the aberration, since it has never been taken out.

Hence the process of reduction of the plate removes the circular aberration terms from the planet's place, but leaves the eccentricity terms.

Hence, to bring the planet up to apparent place, for comparison with the ephemeris, we must add the precession, nutation, and circular aberration.

The resulting apparent geocentric place of the planet contains the whole aberration due to the motion of the Earth's centre.

The whole aberration is equivalent to the alteration in the place of the planet during the light-time.

Hence the usual process of antedating gives us the true comparison between observation and ephemeris, free from the effects of both circular and eccentricity terms.

This is the usual way of presenting the theory. But we may observe that nothing has been said of diurnal aberration. The process of antedating the epoch for interpolation in the ephemeris removes the whole aberration, including the diurnal. The latter is not explicitly restored in the reduction, as are the other aberration terms. Yet the comparison with the ephemeris shows no diurnal variation corresponding with the diurnal aberration. In what way has it been eliminated?

The answer to this question is simple, but not quite obvious. It is connected with the answer to another question which might be propounded. Why do we not antedate the epoch of observation in computing the parallax factors, as we do in interpolating?

In the simple geometry of planetary aberration it is usual to represent the Earth as a point. If it is drawn of finite size, and its rotation during the light-time is considered, we see at once that we ought to antedate the epochs in reducing to the Earth's centre, and at the same time we see that we ought to add the diurnal aberration to the reduction to apparent place. The two quantities are precisely equivalent. We neglect both, and the result is correct.

§ 7. *The Reduction to Apparent Place.*—The reduction of the planet to apparent place affords unexpected opportunities of introducing systematic or semi-systematic discordance.

My attention was called to this, in the first place, by finding that some of the American series contained the short period nutation terms, which were, of course, excluded from the ephemeris of the planet. The tables of Besselian and independent day numbers of the American Ephemeris include these terms—contrary to the practice of other ephemerides—and the fact is not stated with the prominence which is desirable under the circumstances.

This led to an examination of the whole question. The tabular quantities for the reduction from mean to apparent place, as given

in the national ephemerides for the year 1900, are computed with diverse values of the constants of precession, nutation, and aberration (owing to the adoption by the American ephemeris of new constants a year before the other almanacs), and a change was made in all the ephemerides for the year 1901.

In 1908 October I addressed a circular to my colleagues, asking for information as to the method they had followed. This circular specified nineteen different ways in which the reduction might have been made; but the ingenuity of my colleagues had discovered several others, and I think that the number of methods actually pursued is equal to the number of observatories engaged in the reductions. But it happens, fortunately, that the nett difference between the Struve-Peters and the Paris Conference reductions is scarcely sensible in the region of the sky where the planet was; the small differences cancel one another. Hence it was necessary only to remove the short period nutation terms from those series into which they had been inadvertently or deliberately introduced—that is to say, from the Pulkowa, Toulouse, and part of the Minneapolis photographic, and from the Lick, Padua, Pulkowa, and Teramo micrometric series.

The sum of these terms in the R.A. varies between $+0^s{\cdot}021$ and $-0^s{\cdot}016$, as computed from the formulæ employed in the British *Nautical Almanac*. The almanacs are not consistent in the terms they include, and their tables are not competent to give accuracy in the third place of decimals. Hence discordances of some thousandths are common, but they have been treated as accidental.

§ 8. *The Ephemerides.*—All the values of (O – C) published in the Paris Circulars are derived from one or other of the two ephemerides published in Circular 9, based on the elements of Professor Millosevich.

The first gives, in the usual form, the R.A. and Decl. of the planet referred to the true equinox of the date.

The second, which was given by M. Loewy at the request of Professor Turner and myself, gives separately the rectangular ecliptic co-ordinates of the Sun and the planet, referred to the mean equinox for 1900·0. This ephemeris was used in my experimental reduction (*M.N.*, 1904 June). In the course of this I found that the two ephemerides were inconsistent; the first could not be reconstructed from the second. The fact was submitted to M. Loewy, who found that different values of the obliquity of the ecliptic had been employed in different parts of the work; the equatorial rectangular co-ordinates of the planet had been calculated at the Paris Observatory with Leverrier's obliquity; the corresponding co-ordinates of the Sun had been calculated at the Bureau des Longitudes with Newcomb's obliquity.

In Paris Circular 12 M. Loewy published—

(1) The table necessary to correct the ephemeris of Circular 9 for the confusion in the value of the obliquity.

(2) A statement that this ephemeris does not include the whole of the planetary perturbations.

(3) Four new systems of elements calculated by Dr. Gustav Witt of Berlin, the discoverer of the planet.

(4) A table of corrections calculated by Dr. Witt to reduce the old ephemeris to the new elements.

(5) The resulting ephemeris, obtained from the old by simple addition of the tables (1) and (4).

I am indebted to Dr. Witt for the following information on the subject of his elements and corrections.

They are based on new elements calculated for the epoch 1898 Aug. 20 M.T. Berlin (*Untersuchung über die Bewegung des Planeten* (433) *Eros*, von Dr. Gustav Witt, Berlin, 1905). The three systems of osculating elements for 1900 Oct. 31·0, 1900 Dec. 10·0, and 1901 Feb. 8·0 are deduced from the first, with a complete calculation of the planetary perturbations. When the complete perturbations had been applied, it was found that the three portions A, B, C of the ephemeris were still discordant at the points where they overlapped. After a long search Dr. Witt discovered the simple cause. In the elements of Millosevich the values of μ were given to nine significant figures, and the value of log a only in seven-figure logarithms. When it was decided to compute the ephemeris with eight-figure logarithms, the computer had simply added a zero to each value of log a, and had overlooked the fact that the resulting values of log a were irreconcilable with the values of μ. Further, there was a small mistake at the beginning of section B.

For my first general solutions I used the published values of O – C, reduced to conform with the ephemeris of Circular 12. This ephemeris was, however, still open to criticism in several respects.

No details as to its construction had been published. In particular it was desirable to know how the lunar equation in the Earth's motion had been computed. Soon after the appointment of M. Baillaud to the Directorship of the Paris Observatory, I ventured to apply to him for information on this point, and he immediately responded to my request with the ready kindness for which I have had to thank him on this and many other occasions. It appeared that the lunar equation had been computed at the Bureau des Longitudes by the rigorous formulæ given by Newcomb (Tables of the Sun: *Papers of the American Ephemeris*, t. vi. p. 18). But the process of smoothing and of interpolating to smaller intervals had been conducted after the lunar equation had been introduced, which is unsatisfactory. Moreover, there was reason to fear that defects existed in the method of interpolation employed.

§ 9. *The New Paris Ephemeris.* — Eventually M. Baillaud decided, in 1908 November, that it would be best to recompute the entire ephemeris. He entrusted this task to the care of M. Lagarde, chief of the Computing Bureau of the Paris Observatory, who worked with so much energy that the complete new ephemeris was placed in my hands by the middle of February last.

M. Lagarde has kindly given me the following details as to the construction of the new ephemeris.

The ephemeris, in rectangular co-ordinates, for the centre of gravity of the Earth-Moon system, has been computed and polished by smoothing the run of the differences. A similar ephemeris has been made for the planet.

The two combined give an ephemeris in R.A. and Decl. of the planet, as seen from the centre of gravity.

This has been reduced to the true equinox of date with the Struve-Peters constants throughout; has been smoothed again, and reduced to six-hour intervals by interpolation. The lunar equation was computed separately as above, with the tabular values of the place and parallax of the Moon; its effect on the right ascension and declination of the planet was interpolated to six-hour intervals, and applied to the planet ephemeris to reduce to geocentric place; it is also exhibited separately, to facilitate a new determination of the mass of the Moon.

The resulting new Paris Ephemeris is a great improvement on the old. Its theoretical basis is more secure; and it is free from some peculiar irregularities, of obscure origin, which existed in the old. It is worth while to examine them for a moment, because they show very well how the smoothness of third differences in an ephemeris is no guarantee of its accuracy. The following is an extreme case:—

R.A. Ephemeris of Eros. Circular 12.

		3rd Differences.	Error of Ephemeris.
	h	s	s
1900. Dec. 2.	6	·000	·000
	12	+ ·001	− 3
	18	+ 2	− 5
3.	0	5	− 8
	6	+ 2	− 8
	12	+ 3	− 11
	18	− 2	− 13
4.	0	− 2	− 14
	6	0	− 9
	12	− 3	− 5
	18	0	0
5.	0	− 2	+ 3
	6	+ 1	+ 6
	12	− 2	+ 5
	18	+ 3	+ 3

The third differences are sufficiently good; they do not indicate any correction greater than a unit in the last place, while the actual corrections required are very much larger. It is, of course, clear that differencing is good for detecting an isolated error, and no good for detecting anything at all systematic. But it is at first sight rather surprising that differencing will not detect a considerable error probably due to faulty interpolation to halves.

The new Paris Ephemeris is perfectly adapted for the determination of the solar parallax. For the mass of the Moon it is preferable that the motion of the Earth-Moon should be computed by special perturbations, instead of being taken from the Solar Tables. M. Lagarde has therefore computed still another ephemeris upon this latter principle, which will be available for the final discussion of the mass of the Moon.

May I express here my sincere thanks to M. Baillaud and to M. Lagarde for the readiness with which they undertook a severe labour, so soon as an examination of the old ephemeris revealed cause for apprehension.

§ 10. *The Systems of Weights.*—The experience gained in the formation of the Star Catalogue had shown that the contributions of different observatories were by no means of the same weight, and it became a delicate matter to decide what system of weights to adopt. I eventually found that substantial justice would be done if I gave weight unity to a single exposure with an instrument of the astrographic type; gave a slight increase of weight for instruments of greater focal length, and a small decrease for the smaller instruments.

It is quite true that there is not much *a priori* justification for giving weight directly proportional to the number of exposures. But there is evidence *a posteriori* that in this particular case it was nearly the right scale to adopt.

The principal exception is furnished by the Lick photographs. It was assumed that 4 exposures were measured on each plate, though this turns out to be not quite true. But if each plate received weight 4, the total weight of the series would be overwhelming. And since the series consists of a great number of plates made on relatively few nights, so that any error peculiar to the night is repeated a great number of times, the real weight is in this case by no means proportional to the number of exposures. In the solutions made with ephemeris 12 I had given the Lick plates weight 4. In the later solutions I reduced this weight to 2, and eventually to less.

The following table gives the adopted weights:—

Bordeaux .	2
Paris . .	3 (or rarely 2 or 1, corresponding to the number of exposures)
San Fernando	1
Upsala . .	3

Minneapolis	1	
Poulkovo	3	
Toulouse	2 or 1	
Helsingfors	2	
Northfield	3	
Greenwich (Astrographic)	4, 3, 2, or 1	for 4, 3, 2, 1 exposures respectively
,, (Thompson)	5, 4, 3, or 1	
Cambridge	5, 4, 3, or 1	
Lick	2 uniformly	

§ 11. *Determination of Tabular Error.*—In discussing the tabular error of the ephemeris in parallax determinations, it has been usual to represent the error in a series of powers of the time. There are special reasons why this would have been useless in the present case.

The planet traversed a great loop in declination, reaching as far north as $+54^\circ$. Hence a constant error in its longitude would produce an error in its R.A. varying more or less as the secant of the declination.

The fundamental star system probably contains errors in the R.A. varying as some function of the declination, which will reappear in the tabular error of the ephemeris.

The opposition in right ascension took place nearly two months before the nearest approach to the Earth. Hence errors in the heliocentric place of the planet produce effects on its geocentric place which are quite unsymmetrical with respect to opposition.

An error in the mass of the Moon will produce a monthly inequality, and the amplitude will be unsymmetrical with respect to opposition, for the same reason as above.

It seemed best to follow the excellent example set by Greenwich, and deduce the tabular error by graphical processes.

A preliminary examination showed that the terms involving the squares and higher powers of the time were very small; that the correction required by the mass of the Moon was very small; and that the principal correction was a function of the declination, but not simply of the form $a \times b \sec \delta$.

To obtain the tabular error I have used all the observed places of the planet—not only those taken close to the meridian.

The weighted mean of all the observations of a single day gives

$$\Delta\alpha = m + \mathrm{P}f,$$

when the true parallax $= (1 + \mathrm{P}) \times$ the adopted parallax ($8''{\cdot}80$), and f is the mean correction for parallax applied to the observations of the group. A preliminary solution showed that $\mathrm{P} = +0{\cdot}0007$ about, and f is small except at the end of the series. Consequently the term $\mathrm{P}f$ rarely reaches the value $0^s{\cdot}001$, and its uncertainty is insignificant compared with the other irregularities in the determination.

I have made two principal determinations of tabular error—for the ephemeris of Circular 12, and for the new ephemeris.

The representation of the first was very disappointing. It was impossible to draw a curve through the plotted points without abrupt sinuosities. After various fruitless attempts at a smooth curve, I decided to follow the larger sinuosities and to neglect the smaller.

When the new ephemeris arrived, it appeared that a good deal of this trouble was due to the considerable errors of the old, which at the worst varied by as much as $0^s.017$ in 24 hours. With these removed, the representation of the tabular error was much more smooth, but it was exceedingly difficult to decide how to draw a smooth curve through the plotted points. If one took a stretch of, say, 14 days, it was generally impossible to decide on which side of a straight line the curvature lay. It was evident that the smooth curve must have several points of inflexion, but impossible to say how many. There was little hope, then, of finding an algebraical expression which could be fitted to the points.

Finally I used the following device. I divided the curve into sections at the points where the lunar equation vanished, and by a series of least square solutions I fitted straight lines on to each of these sections. If the correction to the mass of the Moon is significant, the convexities of the sections should lie alternately above and below these lines, and the lines themselves should lie alternately high and low. There was no certain trace of such an effect. The lines did not join up precisely, but the errors were slight and irregular. I could think of no better device than to treat these lines as a species of polygonal representation of the curve desired, and to modifiy them graphically on each side of the junctions until a smooth progression was secured from one to the other.

This should secure that the average slope of the curve is correct, which is all that is required for the parallax determination. It will be necessary to re-discuss the tabular error before the final solution for correction of the assumed mass of the Moon.

§ 12. *Formation of the Normal Equations and Solution.*—The normal equations in $\Delta\alpha$ and P were formed with a Brunsviga calculating machine, and were completely checked. The equations were solved with the determinant notation, and the solutions checked by substitution in the normal equations.

In tabulating the results I have given the coefficient of P in the normal equation for P, and also the weight of the determination of P. The difference between the two shows how much has been lost by want of balance of the parallax factors.

A first general solution was made from the comparisons with the ephemeris of Circular 12: in this solution I rejected only such equations as depended upon observations marked "through clouds," with a few that were hopelessly discordant, probably through misprints. The Lick plates received weight 4 in this solution.

The second general solution was made with the new ephemeris. In this solution equations were rejected when they gave a residual

more than three times the mean error of one equation of the corresponding weight. The Lick plates received weight 2.

In all, 99 equations were rejected out of a total of 1645 equations from observations between Oct. 1 and Jan. 19. Observations outside these limits have not been used for the parallax determination.

The equations were grouped in a number of different ways, and solutions were made as follows:—

With the ephemeris of Circular 12 :—

Solution I. All the material divided into four-day groups.

II. The material from each observatory separated, and grouped as far as possible in one- or two-day groups.

This left outstanding a good deal of material which could add no weight to any of these parallax groups. This was all put into a residuum and solved in four-day groups.

III. Ten contributions from each observatory in II. were combined according to their weights.

With the new ephemeris :—

IV. Solution in four-day groups, comparable with I., afterwards combined according to their weights.

V. Solutions in single-day groups; nothing corresponding to this in the first general solution.

VI. Division of solution V. into four periods.

VII. Solution for observatories separately, comparable with II.

VIII. The results of VII. combined according to their weights, comparable with III.

IX. Revision of VII. by rejecting all groups covering more than one day, and all which give a value of P differing from the mean by more than three times the mean error.

X. The contributions made by Greenwich, Lick, Paris, and Cambridge, to VII., combined with revised weights.

§ 13. In the following solutions we employ the uniform notation :—

$\Delta\alpha$ = the residual tabular error, assumed constant for the group.

P = the proportional correction required by the assumed parallax; so that the concluded correction to the parallax

$\Delta\pi = P \times 8''{\cdot}80$.

ϵ_1 = the mean error of one determination of P of weight unity.

The probable error of $\Delta\pi = \dfrac{0{\cdot}6745 \times 8''{\cdot}80 \times \epsilon_1}{(\text{weight})^{\frac{1}{2}}}$.

§ 14.

Table I.

Solutions from 4-day groups.

Date.	Solution I. Ephemeris of Circ. 12. Δα. s	P.	Coefft. of P.	Weight.	Solution IV. New Ephemeris. Δα.	P.
Oct. 4- 7	−·0046	−·00345	...	...	...	...
8-11	+ 75	− 315	60	29	+·0077	−·00375
12-15	− 43	− 67	238	235	− 18	− 54
16-19	− 35	− 117	128	121	− 48	− 98
20-23	+ 10	+ 252	190	189	+ 54	+ 68
24-27	− 29	+ 434	436	431	+ 28	+ 342
28-31	− 80	+ 206	192	191	− 38	+ 217
Nov. 1- 4	+ 41	+ 496	188	183	+ 147	+ 335
5- 8	+ 6	− 509	102	96	+ 5	− 128
9-12	− 4	− 179	416	414	− 1	− 40
13-16	− 11	+ 145	358	351	− 6	− 34
17-20	...	...	32	25	− 16	− 476
21-24	+ 16	− 43	199	167	+ 90	− 303
25-28	+ 30	+ 267	203	193	− 17	+ 164
Nov. 29-Dec. 2	− 75	+ 25	214	211	− 75	+ 107
Dec. 3- 6	+ 105	+ 155	345	313	+ 68	+ 274
7-10	− 49	+ 109	259	242	− 5	+ 213
11-14	+ 25	− 284	75	75	+ 20	− 357
15-18	− 46	+ 54	215	212	− 6	0
19-22	− 17	− 114	250	219	+ 14	− 136
23-26	− 44	− 588	160	115	− 14	− 328
27-30	− 18	− 201	73	44	+ 19	− 643
Dec. 31-Jan. 3	+ 29	− 338	41	30	+ 76	− 1186
Jan. 4- 7	+ 27	− 1097	151	80	+ 1	− 365
8-11	...	...	53	41	+ 66	− 901
12-15	...	...	157	109	+ 14	− 203
16-19	...	...	54	41	− 38	+ 598

The coefficient of P and the weight of the determination refer to Solution IV. Those of Solution I., on the left, are different, owing to the change in the weight assigned to Lick. The numbers serve nearly as well, however, to show the diminution of weight produced by asymmetry in the parallax factors, which is nearly the same in the two solutions.

We have, by combining these separate results according to their weights,—

	Solution I.	Solution IV.
Weight	5864	4357
ϵ_1	$\pm 0''\cdot0456$	$\pm 0''\cdot0346$
$\Delta\pi$	$+0''\cdot0055 \pm 0''\cdot0036$	$+0''\cdot0019 \pm 0''\cdot0031$

§ 15. It will be remembered that the Lick results are duplicated.

Series 1 is reduced with the same stars evening and morning; consequently unsymmetrical about the planet.

Series 2 is reduced with stars symmetrical about the planet; consequently not entirely the same evening and morning.

Table II.

Solutions from Lick Photographs.

		Solution from Eph. Circ. 12.				Coefft Wt		Solution from New Eph.			
		Series 1.		Series 2.				Series 1.		Series 2.	
		$\Delta\alpha$.	P.	$\Delta\alpha$.	P.			$\Delta\alpha$.	P.	$\Delta\alpha$.	P.
		s.		s.				s.	s.	s.	
Oct.	6	−·0055	−·00456	−·0041	−·00629	12	12	−·0010	−·01036	...	...
	12	− 22	− 106	− 15	+ 441	34	33	+ ·24	+ ·195	+ ·0044	+ ·0069
	13	− 66	− 865	− 120	− 206	36	35	− 1	− 967	− 69	− 29
	14	− 138	+ 207	− 86	+ 113	59	56	− 124	+ 96	− 67	+ 4
	15	− 45	− 235	+ 10	− 262	60	59	− 13	− 288	+ 25	− 27
	16	− 98	+ 634	− 25	+ 62	58	56	− 52	+ 687	+ 1	+ 11
	21	+ 78	+ 194	+ 83	+ 174	74	74	+ 199	+ 209	+ 187	+ 23
	24	+ 58	+ 125	+ 87	+ 579	65	60	+ 120	+ 209	+ 155	+ 60
	26	− 32	+ 15	− 76	+ 318	108	108	+ 12	+ 47	+ 16	+ 35
	29	+ 23	+ 338	− 54	+ 18	66	58	+ 52	+ 397	+ 14	+ 4
Nov.	3	+ 138	+ 804	+ 101	+ 603	114	114	+ 352	+ 785	+ 265	+ 51
	10	− 102	− 761	+ 52	− 683	87	83	− 58	− 744	+ 68	− 70
	28	+ 32	+ 460	− 30	+ 202	120	119	− 10	+ 370	− 64	+ 21
	29	− 46	+ 187	− 1	+ 88	158	155	− 110	+ 145	− 133	+ 4
Dec.	5	+ 178	+ 184	+ 127	+ 263	140	136	+ 125	+ 270	+ 71	+ 35
	6	+ 137	+ 220	+ 94	+ 190	138	134	+ 118	+ 346	+ 100	+ 27
	7	− 36	+ 59	− 33	+ 186	133	128	+ 54	+ 150	+ 47	+ 31
	24	− 122	− 226	− 129	− 523	62	55	− 86	− 87	− 100	− 20

When these are combined according to their weights they lead to the following :—

Lick Contributions to Solution II.

	Series 1.	Series 2.
Weight	2972	3016
ϵ_1	±0·0506	±0·0433
$\Delta\pi$	+0″·0105±0″·0055	+0″·0107±0″·0047

The coefficients and weights in the table belong to the later solution. It will be noticed that the Lick material consists almost entirely of complete and well-balanced series: the odd plates were not measured.

Lick Contributions to Solution VII.

	Series 1.	Series 2.
Weight	1463	1461
ϵ_1	±0·0346	±0·0297
$\Delta\pi$	+0″·0149±0″·0054	+0″·0148±0″·0046

The reduction from 4 to 2 in the weight assigned to each Lick equation should reduce the corresponding value of ϵ_1 in the ratio $1 : \sqrt{2}$. The actual reduction, as calculated, has almost precisely this value; and the probable errors of $\Delta\pi$ remain the same.

In both solutions Series 2 comes out decidedly better than Series 1. We may apparently conclude that the influence of irregularity in the star places is less serious than the influence of asymmetry of the stars with respect to the planet in the centre of the field.

There are three points in these solutions worthy of investigation:

1. The great change in the value of $\Delta\pi$ with the change of ephemeris.

2. The absence of improvement in the probable error.

3. The large size of the probable error compared with that assigned in *L.O.B.* 150 to the Lick discussion of this material. We shall return to these points.

§ 16. The Greenwich observations of the planet have been subjected to a very fine discussion in the recently published "Observations of the Planet Eros 1900–1901: Appendix to the Volume of Greenwich Observations for the year 1905." To my table of solutions of the Greenwich material I have added the Greenwich solutions for comparison. The quantities P in this last column have been formed from the fifth column of Greenwich Table 25, by dividing by 8·80. I have carried the division to one place more than is significant, in order to facilitate comparison with my own results.

Table III.

Solutions from Greenwich Photographs.

Date.	Sol. from Eph. Circ. 12. Δα. s	P.	Coefft.	Wt.	Sol. from New Ephem. Δα. s	P.	Greenwich Solution. Δα.	P.
Oct. 4– 7	– ·0206	– ·01578	39	3	...	...	...	...
8–11	+ 368	+ 1972	28	4	...	...	...	...
12–15	– 63	– 860	7	4	– ·0044	– ·00493	Oct. 14, 15	– ·00513
20	– 145	+ 1296	5	5	– 97	+ 1259		+ 1334
21	– 118	+ 116	37	28	– 56	+ 224		+ 80
26	– 52	+ 251	81	76	+ 13	+ 28		+ 68
27	– 62	+ 469	67	65	– 20	+ 409		+ 433
28, 29	– 99	– 29	62	52	– 68	– 34		– 103
Nov. 6, 7, 8	– 156	– 330	36	36	– 89	+ 206*	Nov. 8, 9	– 137
9	– 19	+ 533	33	33	– 16	+ 434	9, 10	+ 137
10	+ 6	– 38	42	42	0	– 19	10, 11	+ 137
13	– 57	– 90	115	114	– 38	– 152		– 125
14, 15	– 11	– 822	58	54	– 22	– 600*		– 764
22	– 25	+ 130	68	48	+ 112	– 367	22, 23	+ 103
23	– 24	– 276	14	8	+ 22	– 318		. .
27	+ 59	– 60	46	30	+ 1	– 64		– 57
Dec. 7	– 113	+ 599	35	21	– 71	+ 714	Dec. 6, 7	+ 616
9	– 106	+ 425	12	12	...	...	9, 10	+ 125
13	– 62	– 642	33	32	– 28	– 600		– 502
15	– 39	– 257	78	70	+ 14	– 312	15, 16	– 205
17	– 74	– 623	16	1	+ 31	– 240		...
19	+ 44	+ 173	64	60	+ 24	+ 153		+ 34
21	– 176	+ 380	67	39	– 72	+ 418		+ 376
26	– 97	– 1255	4	3	..	...		...
28	– 214	+ 1613	24	3	– 169	+ 1503	28, 29	+ 376
Jan. 5	– 168	– 558	50	8	– 186	– 298		0
8	...	...	20	9	– 102	– 366	Jan. 8, 9	– 935
9	...	...	8	7	+ 102	– 508		...
14	...	...	39	21	– 48	+ 265	13, 14	+ 342
15	...	...	32	25	+ 66	– 64		+ 388
18	...	...	13	11	– 61	+ 1049	17, 18	+ [3158]

When these solutions are combined according to their weights they lead to the following:—

* 1 plate rejected from the second solution.

Greenwich contributions to

	Solution II.	Solution VII.
Weight	864	902
ϵ_1	$\pm 0''\cdot0249$	$\pm 0''\cdot0215$
$\Delta\pi$	$+0''\cdot0002 \pm 0''\cdot0050$	$-0''\cdot0003 \pm 0''\cdot0043$

The Greenwich solution of the same material gave

$$\Delta\pi = 0''\cdot000 \pm 0''\cdot0044.$$

The excellent accordance of these three solutions, referred to three different ephemerides, and three different determinations of tabular error, is most satisfactory. It shows that the Greenwich observations have an admirable stability: alterations in the method of discussion, the ephemerides, or the tabular error affect the results hardly at all.

§ 17. The data of the two solutions of the Paris photographs are given in the following table.

Table IV.

Solutions from Paris Photographs.

	Soltn. from Eph. Circ. 12.					Soltn. from New Eph.	
	$\Delta\alpha$.	P.	Coefft.	Wt.	$\Delta\alpha$.	P.
	s				s	
Oct. 17	$-0\cdot0115$	$+0\cdot01868$	8	7	$-0\cdot0146$	$+0\cdot01774$
19	− 77	− 508	10	7	− 138	− 433
22	+ 66	− 365	19	19	+ 144	− 399
23	− 84	+ 294	18	18	− 38	+ 355
25, 26	− 112	+ 109	18	14	− 43	+ 25
27	− 117	+ 1691	17	16	− 15	+ 1098
Nov. 7	− 123	− 1427	35	8	− 93	− 1687
8	− 179	− 2270				
10	+ 7	− 133	9	7	− 2	+ 12
Dec. 7	+ 62	− 1745	37	3	...	...
17, 18	...	...	14	14	+ 14	+ 1338
18	+ 46	+ 1185	12	10	...	...
19	+ 25	+ 21	13	13	+ 10	+ 41
21	− 26	− 178	7	4	− 153	− 1817
28	− 4	− 1687	17	8	+ 47	− 1810
Jan. 4	+ 34	+ 570	6	5	+ 11	+ 848
5	− 269	+ 1730	24	3	− 259	+ 1731
6	...	...	33	17	+ 37	+ 799
9	...	...	16	12	+ 112	− 398
13	...	...	11	9	− 71	+ 233
14	...	...	23	15	+ 70	− 1124
15	...	...	19	13	+ 95	− 407
17	...	...	14	7	+ 12	− 1135

Combining these separate results according to their weight we have—

Paris contribution to

	Solution II.	Solution VII.
Weight	201	216
ϵ_1	$\pm 0''.0339$	$\pm 0''.0326$
$\Delta\pi$	$+0''.0137 \pm 0''.0142$	$+0''.0002 \pm 0''.0132$

§ 18. The Cambridge results are given in similar form :—

Table V.

Solutions from Cambridge Photographs.

		Solution Eph. Circ. 12.					Solution New Ephem.		
		$\Delta\alpha$.		P.	Coefft.	Wt.	$\Delta\alpha$.		P.
		s					s		
Oct.	12–15	+ ·0325	−	·01682	6	5	+ ·0241	−	·02014
	27	− 66	+	1103	24	23	− 52	+	1060
Nov.	9	+ 16	+	50	57	55	+ 18	+	1
	10	− 38	+	428	57	56	− 49	+	484
	13	− 64	+	324	28	26	− 42	+	257
	14, 15	− 120	−	7	38	35	− 109	−	14
	22	+ 25	−	558	45	4	+ 95	−	610
	23	+ 148	−	681	37	4	+ 159	−	697
Dec.	13	− 74	−	310	17	17	− 65	−	210
	15	− 9	+	118	35	32	+ 8	+	89
	16, 17	− 61	+	584	22	21	− 41	+	567
	19	+ 48	−	35	7	6	− 1	−	109
	21	+ 40	−	441	34	20	+ 114	−	424

These give the following :—

Cambridge contribution to

	Solution II.	Solution VII.
Weight	306	305
ϵ_1	$\pm 0''.0230$	$\pm 0''.0241$
$\Delta\pi$	$+0''.0141 \pm 0''.0078$	$+0''.0119 \pm 0''.0082$

§ 19. Inasmuch as I hope that the full details will be published at an early date, I have not thought it necessary to give the contributions of other observatories in quite such complete form. We

may summarise them as follows: the series are not sufficiently complete for determination of their probable errors from internal agreement.

Contributions to	Solution II.		Solution VII.	
	Wt.	$\Delta\pi$.	Wt.	$\Delta\pi$.
Bordeaux . .	33	$-0''\cdot0906$	23	$-0''\cdot0039$
Helsingfors . .	22	$+0''\cdot700$	39	$+0''\cdot262$
Minneapolis . .	109	$-0''\cdot206$	105	$-0''\cdot245$
Northfield . .	72	$-0''\cdot350$	35	$-0''\cdot165$
Oxford . . .	95	$-0''\cdot285$	95	$-0''\cdot056$
Poulkovo . .	15	$+1''\cdot100$	4	$-0''\cdot658$
San Fernando .	1	$+1''\cdot408$	...	...
Toulouse . .	33	$-0''\cdot134$	41	$-0''\cdot363$
Upsala . . .	30	$+0''\cdot669$	39	$+0''\cdot709$

The residuum in Solution II., divided into 4-day groups and solved, gives—

Weight	447
ϵ_1	$\pm0''\cdot0474$
$\Delta\pi$	$+0''\cdot0239\pm0''\cdot0133$

The great increase in the value of ϵ_1 in this solution is no doubt partly due to the errors in star places for these scattered observations, but it must not be put down entirely to the discredit of the star places. The observatories whose results are less accurate, and have had perhaps rather too much weight given to them, contribute largely to the residuum.

§ 20. Solution V. divides the whole material into single-day groups; or occasionally, when the observations of a single day gave no solution, two or more days have been combined. In no case has a day which gave a fair solution by itself been joined with another. The whole available material is utilised in this solution. Normal equations were formed for each group and solved by least squares.

The differences between the coefficient of P in the normal for P, and the weight of the determination, give an interesting criterion of the waste of material due to want of balance of parallax factors.

Table VI.

Solutions from Single-Day Groups with New Ephemeris.

	Coefft.	Wt.	Δα. s	P. s
Oct. 8	15	5	−·0076	−·02621
9	11	4	+ 138	+ 1242
10	20	11	+ 99	− 783
11	13	8	+ 129	+ 590
12	46	38	+ 16	+ 596
13	46	46	+ 7	− 338
14	60	57	− 59	+ 5
15	86	86	+ 5	− 301
16	66	60	− 11	+ 102
17	11	10	− 108	+ 947
18	17	11	− 10	− 596
19	35	34	− 88	− 330
20	8	8	− 79	+ 665
21	121	121	+ 82	+ 401
22	24	24	+ 120	− 37
23	37	36	+ 20	+ 123
24	77	77	+ 171	+ 499
25	22	18	+ 73	+ 469
26	223	217	+ 7	+ 99
27	114	114	− 18	+ 607
28, 30, 31	65	11	− 240	+ 1399
29	127	88	− 8	+ 340
Nov. 1, 2, 4	49	43	+ 76	+ 4
3	139	138	+ 206	+ 369
5, 6	22	7	+ 163	+ 1680
7	51	50	+ 35	− 340
8	29	25	− 22	− 457
9	121	111	+ 13	+ 44
10	249	244	− 4	− 207
11, 12	46	29	+ 3	+ 562
13	232	231	+ 6	+ 75
14	41	22	− 33	− 100
15	85	46	− 48	− 460
21, 24	14	12	+ 105	− 1475
22	134	97	+ 56	− 124
23	51	45	+ 102	− 149
25, 26	32	32	+ 48	+ 189
27	52	36	− 28	− 59
28	120	119	− 64	+ 218
29	166	163	− 80	+ 14
30	29	29	− 110	+ 620
Dec. 1, 2	19	19	− 19	+ 46
3, 4	3	2	+ 207	+ 5677
Dec. 5	140	136	+ ·0071	+ ·00356
6	202	163	+ 73	+ 142
7	217	169	− 6	+ 158
8, 9	29	25	− 44	+ 96
10	14	11	+ 68	+ 1535
11, 12	16	14	+ 151	+ 414
13	52	51	− 38	− 487
14	7	2	+ 334	− 1277
15	113	102	+ 15	− 193
16	26	26	− 43	+ 429
17	37	23	− 27	− 155
18	39	31	+ 24	+ 27
19	113	106	+ 26	− 140
20	17	11	+ 47	− 1316
21	110	88	− 7	+ 90
22	9	8	+ 27	− 382
23	16	13	+ 42	− 1349
24	83	67	− 86	− 106
25, 26	61	32	+ 46	− 497
27	4	4	− 42	− 2390
28	59	29	+ 16	− 596
29	10	6	+ 4	+ 85
30				
31	22	14	− 21	− 544
Jan. 1, 2	19	15	+ 157	− 1670
3				
4	21	21	+ 55	− 231
5	87	18	− 142	+ 33
6	43	18	+ 16	+ 841
7				
8	20	13	− 189	+ 249
9	28	24	+ 113	− 837
10	5	2	+ 177	− 2935
11				
12	4	1	− 131	+ 408
13	26	18	− 43	+ 509
14	73	47	− 8	− 277
15	53	42	+ 91	− 348
16	7	6	− 88	− 60
17	29	17	+ 14	+ 67
18	14	13	− 49	+ 934
19	4	3	− 142	+ 2583

When these solutions are combined according to their weight we have—

	Solution V.
Weight	3732
ϵ_1	$\pm 0''.0274$
$\Delta\pi$	$+0''.0041 \pm 0''.0026$

And when they are divided into four parts, and solutions in each part combined, we have—

	Solution VI.		
	Weight	ϵ_1	$\Delta\pi$
Oct. 1–Oct. 23	559	$\pm 0''.0278$	$+0''.0039$
Oct. 24–Nov. 16	1381	$\pm 0''.0310$	$+0''.0088$
Nov. 17–Dec. 22	1416	$\pm 0''.0245$	$+0''.0048$
Dec. 23–Jan. 19	376	$\pm 0''.0274$	$-0''.0158$

§ 21. Solutions II. and VII. are composed of contributions from individual observatories, kept separate.

If we now combine these according to their weights we have—

	Solution III. Ephemeris of Circ. 12.	Solution VIII. New Ephemeris.
Weight	5244	3265
ϵ_1	$\pm 0''.0354$	$\pm 0''.0259$
$\Delta\pi$	$+0''.0086 \pm 0''.0029$	$+0''.0073 \pm 0''.0027$

Solution III. includes the residue. If we omit the residue we have—

Weight 4797 $\quad \Delta\pi + 0''.0072$.

§ 22. Some of the individual solutions which contribute to the various parts of Solution VII. are discordant; and some of them depend upon observations made on more than one day, and involving different stars. If we omit all the latter, and also all those which give a $\Delta\pi$ differing from the mean by more than three times the mean error for a contribution of that weight, the principal series give the following revised results :—

	Solution IX.	
	Weight.	$\Delta\pi$.
Cambridge . . .	300	$+0''.0162$
Greenwich . . .	756	+ 30
Lick Series 2 . .	1378	+ 194
Paris	149	− 122

§ 23. Inspection of the internal probable errors of the principal contributions to Solution VII. suggests that the adopted weights need revision.

The mean errors for a determination of P of weight unity come out respectively—

Greenwich	±0·0215
Cambridge	241
Lick Series 2	297
Paris	326

If we bring the other three to the standard of Greenwich, we must multiply their respective contributions by factors proportional to the reciprocal of the squares of these quantities; *i.e.* by 0·794 and 0·523 and 0·435.

We thus obtain—

	Solution X.
Weight	2002
ϵ_1	±0·0215
$\Delta\pi$	+0″·0071±0″·0028

§ 24. As a preliminary to bringing the final results together, we may note the following points.

Few observatories have been able to furnish a substantial independent contribution to the determination of the parallax itself, but the others have furnished the bulk of the observations for the star catalogue.

If a is the correction for parallax already applied, and the true parallax is $(1 + P) \times$ the assumed, our equations of condition become

$$\Delta a + a\mathrm{P} + m = 0.$$

No term depending upon the time is retained; that is to say, it is assumed that the variation of the tabular error with the time has been completely determined and eliminated.

Each observation of the planet gives an equation of condition of the above form. We have next to decide how to group them.

It is probably safe to suppose that the variation of the tabular error is sufficiently well determined over intervals of four days. But different stars are used during that interval, and their errors will enter into the determination. If we restrict the grouping to intervals of one day we get rid of part of this effect, but at the expense of much loss of material. If we go further, and group separately the observations of each observatory for each day, we practically eliminate the star places, but with renewed heavy loss of material.

The adoption of the new ephemeris has somewhat diminished the probable error. But the improvement is not very great, and it is evident that the principal irregularities are inherent in the published values of O – C.

The adoption of the new ephemeris has somewhat increased the value of $\Delta\pi$. But this is due principally to the Lick series, which have shown themselves remarkably sensitive to the change.

The Greenwich series, on the other hand, are extremely stable. Whether they are reduced with the ephemerides of Circular 9, or of Circular 12, or with the new; or which determination of the tabular error is used, makes little difference.

§ 25. We will now bring together the principal results for comparison :—

	With Eph. Circ. 12. $\Delta\pi$.	With New Eph. $\Delta\pi$.
4-day groups .	Sol. I. $+0''\cdot0055\pm0''\cdot0036$	Sol. IV. $+0''\cdot0019\pm0''\cdot0029$
Cambridge . .	Sol. II. $+0\cdot0141\pm0\cdot0078$	Sol. VII. $+0\cdot0119\pm0\cdot0082$
Greenwich . .	+ 2 50	− 3 43
Lick Series 2 .	+ 107 47	+ 148 46
Minneapolis .	− 206 ...	− 245 ...
Northfield . .	− 350 ...	− 165 ...
Oxford . .	− 285 ...	− 56 ...
Paris . . .	+ 137 142	+ 2 132
Combination of observatory solutions	Sol. III. $+0\cdot0086\pm0\cdot0029$	Sol. VIII. $+0\cdot0073\pm0\cdot0031$
1-day groups .	... ...	Sol. V. $+0\cdot0041\pm0\cdot0026$
Camb., Green., Lick., Paris, with new weights	... ...	Sol. X. $+0\cdot0071\pm0\cdot0028$

The accordance between the different combined solutions is in striking contrast with the divergence between the results from different observatories. I think that we may conclude that any outstanding improvements in ephemeris, tabular correction, or method of combination would have a very small effect upon the parallax. The serious question for discussion is—Why do Minneapolis and Northfield give a value of $\Delta\pi$ so low, and Lick and Cambridge a value so high?

I believe that we may find an explanation in the fact discovered at Greenwich, that the parallax deduced depends on the magnitude of the comparison stars. (See Greenwich Tables 28 and 29, *loc. cit.*) The fainter stars, at least near the centre of the plate, are at Greenwich displaced towards the zenith by comparison with the *repère* stars. Hence when bright *repère* stars are used in the reduction, the parallax comes out small. Can we extend this proposition, and suppose that when the comparison stars are fainter than the planet the parallax comes out large?

Minneapolis and Northfield used bright stars, and no reduction to standard with fainter stars has been possible. They give a small value of $\Delta\pi$ closely resembling that found at Greenwich from the *repère* stars.

Paris also used *repère* stars, but I have been able to make the reduction to standard. The Paris result is only a little small.

The Greenwich comparison stars were fainter than the *repère*,

but probably a little brighter than the planet. The Greenwich result is a little small.

The Lick and Cambridge comparison stars were decidedly fainter than the planet. Their correction $\Delta\pi$ is decidedly large.

Our results are therefore consistent with the hypothesis that the deduced parallax depends to some extent upon the magnitude of the comparison stars.

We have decisive evidence only in the case of the Greenwich astrographic telescope; and the effect may, of course, be peculiar to the telescope. For the others it must be investigated, and the investigation is comparatively easy. We have only to find from the residuals in the solutions of the plates if the stars of outstanding magnitude, either bright or faint, have an apparent diurnal parallax. I hope to take up this question in the near future.

§ 26. But meanwhile we must decide what shall be taken as the best result from the above solutions.

After taking account of all the considerations above noted, and remembering that when we work with the mean of a number of exposures the result tends to be a little small (see Greenwich Observations of Eros, p. lx), it seems to me that we may adopt

$$\Delta\pi = +0''\cdot007 \pm 0''\cdot0027$$

as the most probable result of our solutions.

This is derived from the right ascensions alone. In the Lick and Cambridge series the declinations were not measured. At Greenwich they were discussed, and gave the same value of the parallax as the right ascensions, but with very little weight. I do not think it worth while to discuss the remaining observations of declination.

§ 27. *The Residual Tabular Errors.*—In some cases these are rather large, and might seem to require a further correction to the adopted tabular error. I think it has been sufficiently shown that this would not affect the parallax. We will therefore reserve the discussion of these residuals for the determination of the mass of the Moon, which will be undertaken as soon as the latest Paris ephemeris is received.

§ 28. *The supposed Inequality in the Place of the Planet depending on the Light-variation.*—In my early work I thought I had found evidence of such an inequality, with semi-amplitude about $0''\cdot03$ and period $2^h\ 38^m$. The much more extensive material now available does not confirm this at present. Perhaps the period is not precisely $2^h\ 38^m$, and there might very probably be secular terms in the epochs of minimum depending on the phase angle. Further investigation will be made; and I shall be grateful for any photometric observations of the planet made from October to December 1900. The published information is exceedingly slight.

§ 29. At the moment of completing the above solutions I received, by the kindness of Professor Perrine, an advance proof

of *Lick Observatory Bulletin* 150. He gives as the result of his discussion of the Lick series,

$$\Delta\pi = +0''\cdot0067 \pm 0''\cdot0025.$$

The result is in excellent agreement with my general result, but decidedly different from the result which I have given above from my own solutions of the material which the Lick Observatory kindly placed at my disposal in advance of publication. The probable error is also very much smaller than that which I found. For the moment I am not able to suggest the reason for this divergence, which must be examined. But it may be interesting to call attention to the various probable errors for $\Delta\pi$ derived at Lick Observatory. Thus—

P.E. of $\Delta\pi$ derived from 126 equations (all)	$\pm0''\cdot0027$
,, 96 ,, (30 with large residuals rejected)	$\pm0''\cdot0018$
P.E. of $\Delta\pi$ derived from 18 daily means	$\pm0''\cdot0052$

Thus the P.E. derived from daily means, which corresponds practically to the method I have used, is actually larger than mine; I cannot suggest a reason why alternative methods should give a result so much smaller that they correspond to a weight four times as great.

§ 30. The present paper deals with the photographic results for the parallax. The discussion of the micrometric observations is practically complete, and will be presented to the Society without delay.

I hope also that the discussion of the mass of the Moon may be completed within a few months.

§ 31. In presenting the conclusions of the discussion upon which I have been engaged for so long, I must not omit to thank all my colleagues, who have shown me throughout the greatest kindness and given me the most cordial help. My best thanks are due also to the assistants who have been engaged in the calculations at Cambridge; to the Royal Society, which has made grants towards the cost of this assistance; and finally, to the Director of the Cambridge Observatory, who has permitted me to occupy a large part of my time in this work, and has given me every encouragement.

Cambridge Observatory:
1909 *May* 13.

The Constants of the Physical Libration of the Moon.

By F. J. M. Stratton, M.A.

(*Abstract.*)

The following are the results obtained from a fresh reduction of the observations of Mösting A made by Schlüter at Königsberg in the years 1841–3. The observed positions were reduced so as to give the apparent selenographical latitude (β) and longitude (λ) of the crater at each observation. Two reductions were undertaken: one was based on the previous work of Dr. Franz on these observations; in the second reduction an assumption of Dr. Franz with regard to the constancy of the focal setting of the heliometer was not adopted. One element, which had been overlooked by Dr. Franz, was taken into account in both reductions, namely, the excess (dh) of the radius of the moon to Mösting A over the observed mean radius to the limb.

Two solutions were made for each reduction. In the one case, the *unrestricted* case, the residuals between the observed β, λ and an assumed constant β, λ were analysed by the method of least squares for corrections to the assumed constants, and for certain periodic terms; no theoretical connection between the coefficients of these periodic terms was assumed in the analysis. The value of one of the unknown constants $\left(f \equiv \frac{(C-B)\,B}{(C-A)\,A}\right)$ was then derived from the coefficients of these periodic terms. In the second or *restricted* solution, a connection between the coefficients was assumed beforehand, according to the scheme worked out by Dr. Hayn,* and the values of f and of the other constants were obtained on this theoretical basis.

The following four solutions were thus obtained:—

1. Unrestricted solutions.

(*a*) With Dr. Franz's assumption:

From Latitude Equations.	From Longitude Equations.
$\beta = -3^\circ\,9'\,36'' \pm 47''$	$\lambda = -5^\circ\,9'\,18'' \pm 42''$
$I = 1^\circ\,28'\,39'' \pm 70''$	$I = 1^\circ\,35'\,2'' \pm 206''$
$f = 0{\cdot}51 \pm 0{\cdot}09$	$f = 0{\cdot}38 \pm 0{\cdot}04$
$dh = +8''{\cdot}8 \pm 2''{\cdot}2$	$dh = +1''{\cdot}9 \pm 2''{\cdot}2$
$\delta\beta = -106'' \sin\omega - 17'' \cos\omega - 77'' \sin(g+\omega-\lambda)$	$\delta\lambda = -66'' \sin g + 168'' \sin g' - 26'' \sin 2\omega$
p.e. of observation $= 61''$	p.e. of observation $= 89''$

* *Selenographische Koordinaten*, ii. p. 52.

(*b*) Without Dr. Franz's assumption:

From Latitude Equations.	From Longitude Equations.
$\beta = -3^\circ\ 10'\ 2'' \pm 54''$	$\lambda = -5^\circ\ 7'\ 1'' \pm 58''$
$I = 1^\circ\ 28'\ 34'' \pm 81''$	$I = 1^\circ\ 34'\ 8'' \pm 281''$
$f = 0{\cdot}66 \pm 0{\cdot}11$	$f = 0{\cdot}50 \pm 0{\cdot}05$
$dh = +8''{\cdot}2 \pm 3''{\cdot}1$	$dh = +5''{\cdot}0 \pm 3''{\cdot}0$
$\delta\beta = -125'' \sin\omega - 23'' \cos\omega - 50'' \sin(g+\omega-\lambda)$	$\delta\lambda = +20'' \sin g + 148'' \sin g' - 51'' \sin 2\omega$
p.e. of observation $= 69''$	p.e of observation $= 121''$

2. Restricted solutions.

(*a*) With Dr. Franz's assumption:

From Latitude Equations.	From Longitude Equations.
$\beta = -3^\circ\ 9'\ 28'' \pm 40''$	$\lambda = -5^\circ\ 9'\ 0'' \pm 11''$
$I = 1^\circ\ 27'\ 31'' \pm 66''$	$I = 1^\circ\ 33'\ 40'' \pm 207''$
$f = 0{\cdot}49 \pm 0{\cdot}03$	$f = 0{\cdot}42 \pm 0{\cdot}03$
$dh = +7''{\cdot}9 \pm 2''{\cdot}5$	$dh = 3''{\cdot}0 \pm 0''{\cdot}5$
$\delta\beta = -93'' \sin\omega + 7'' \cos\omega + 11'' \sin(g+\omega-\lambda)$	$\delta\lambda = -25'' \sin g + 154'' \sin g' - 14'' \sin 2\omega$
p.e. of observation $= 61''$	p.e. of observation $= 90''$

(*b*) Without Dr. Franz's assumption:

From Latitude Equations.	From Longitude Equations.
$\beta = -3^\circ\ 10'\ 40'' \pm 46''$	$\lambda = -5^\circ\ 8'\ 25'' \pm 16''$
$I = 1^\circ\ 29'\ 19'' \pm 77''$	$I = 1^\circ\ 33'\ 20'' \pm 279''$
$f = 0{\cdot}60 \pm 0{\cdot}07$	$f = 0{\cdot}46 \pm 0{\cdot}04$
$dh = +4''{\cdot}0 \pm 3''{\cdot}0$	$dh = +3''{\cdot}0 \pm 0''{\cdot}7$
$\delta\beta = -114'' \sin\omega + 7'' \cos\omega + 11'' \sin(g+\omega-\lambda)$	$\delta\lambda = -24'' \sin g + 141'' \sin g' - 17'' \sin 2\omega$
p.e. of observation $= 70''$	p.e. of observation $= 121''$

If we put $dh = 0$ in the equations giving the solution 2(*a*), we ought to get a solution closely resembling Dr. Franz's solution. We get in fact:

From Latitude Equations.	From Longitude Equations.
$\beta = -3^\circ\ 11'\ 30'' \pm 7''$	$\lambda = -5^\circ\ 9'\ 56'' \pm 6''$
$I = 1^\circ\ 30'\ 57'' \pm 8''$	$I = 1^\circ\ 25'\ 52'' \pm 203''$
$f = 0{\cdot}58 \pm 0{\cdot}05$	$f = 0{\cdot}43 \pm 0{\cdot}03$
$\delta\beta = -110'' \sin\omega + 7'' \cos\omega + 11'' \sin(g+\omega-\lambda)$	$\delta\lambda = -25'' \sin g + 151'' \sin g' - 14'' \sin 2\omega$
p.e. of observation $= 61''$	p.e. of observation $= 95''$

Combining the two sets of equations with weights 2·4466 and unity for the latitude and longitude equations respectively (the weights assigned by Dr. Franz), this solution gives :

$$\beta = -3^\circ\ 11'\ 23''$$
$$\lambda = -5^\circ\ 9'\ 58''$$
$$I = 1^\circ\ 30'\ 59''$$
$$f = 0{\cdot}48$$

a result in pretty close accordance with Dr. Franz's solution of the same observational material.

The final conclusion is that Dr. Franz's results in the chief points where they differ from Dr. Hayn's are confirmed by the present investigation. If the uncertain element dh, neglected by Dr. Franz, is taken into account an alternative solution may be substituted for Dr. Franz's, namely 2(b) above. Combining the two sets of constants there given, we have :

$$\beta = -3^\circ\ 10'\ 40'' \pm 46''$$
$$\lambda = -5^\circ\ 8'\ 25'' \pm 16''$$
$$I = 1^\circ\ 29'\ 37'' \pm 71''$$
$$f = 0{\cdot}50 \pm 0{\cdot}03$$
$$dh = +3''{\cdot}0 \pm 0''{\cdot}7$$
$$\delta\beta = -95'' \sin\omega + 7'' \cos\omega + 11'' \sin(g + \omega - \lambda)$$
$$\delta\lambda = -22'' \sin g + 129'' \sin g' - 20'' \sin 2\omega$$

The difference between the results derived from Schlüter's observations and those recently obtained by Dr. Hayn remains. But this work shows that the difference lies in the observations themselves rather than in the theoretical treatment. The great need at the present moment is for some fresh observational material continued over a period of several years and free from the errors of the limb which affect so adversely the measures of this and other investigations.

It should be added that part of the expense of checking the calculations was borne by a grant from the Government Grant Committee of the Royal Society.

1909 *May* 14.

Aberration considered in relation to the two Star-Streams.

By A. S. Eddington, M.A., M.Sc.

The suggestion here considered with regard to the two star-streams which appear to exist throughout the sky was made to me by Mr. Stratton nearly two years ago, and recently and independently by Professor Turner.* I believe that the result of examining the data of the observed proper motions is to show that it is not a correct explanation of the phenomena; but it seems worth while to publish it, not only on account of its intrinsic interest, but because the published investigations of the systematic motions of the stars hardly afford a means of testing it, and it is only by reference to the original data that we are able to ascertain whether it is or is not accordant with the facts.

The suggestion (practically in Professor Turner's words) is as follows:—

(*a*) The Sun's motion in space gives rise to an aberration effect, which, however, is usually neglected. The displacement of the stars from this cause is constant, and we may as well use the displaced as the true places.

(*b*) But if the solar motion were to change, there would be a change of this aberration displacement. An *acceleration* of the Sun would produce, by aberration, changes in the apparent positions of the stars very similar to those which its *velocity* produces by displacement; with this difference, however, that the aberration effect would be independent of the stars' parallaxes, whereas the displacement effect depends on them directly.

(*c*) Were it not for this difference, the effects of the two vectors (α) displacement and (β) change of velocity would compound, according to the vector law, and be inseparable by observation.

(*d*) But the difference specified in (*b*) gives an independent existence to the two vectors; so that, in a sense, the Sun has two apparent velocities relative to the stars.

(*e*) Is this a possible explanation of the two star-streams? The attractiveness of the explanation lies in the accounting for the complete intermingling of the two streams. The duplicity is in fact removed from the stars to the Sun.

Consider, for example, in a universe in which the true motions of the stars are everywhere haphazard, the two groups of stars which are respectively (1) very near to the Sun and (2) very distant from it. For the former the displacement effect (which is proportional to the parallax) will be great in comparison with the aberration effect, so that the latter effect may be neglected. This group of stars will accordingly appear to form a drift, whose motion relative to the Sun would be parallel to and opposite to the true solar displacement. On the other hand, for the very distant stars the displacement effect will be vanishingly small; and assuming the aberration effect to be sensible, that will be the only change of

* *Monthly Notices*, lxix. p. 412, sec. 22.

position observed. These stars will accordingly appear to form a drift moving parallel to the direction of the solar acceleration. When the stars intermediate between these two extremes are taken into consideration, the division into two drifts will be theoretically less marked; but it is clear that we can in this way account for the two "favoured directions of motion," and there seems no reason to doubt that the main features of the distribution of the directions of motion of the stars would be satisfactorily explained by this theory.

It is, however, possible to apply a crucial test, which will determine whether the double star-stream phenomenon arises from the cause suggested. Suppose that, as usual, the proper motions of stars in a small area of the sky are considered. For all these, the aberration effect will be a sensibly constant though unknown angular amount, since it is independent of the parallax, and depends only on the position on the celestial sphere. Let it be u'' per century in R.A. and v'' per century in Dec. If then we correct all the observed proper motions by the amounts $-u''$, $-v''$, the aberration effect will be eliminated completely, and the residual proper motions should no longer show any evidences of the two streams. The question is—Can we for any region find values of u and v for which this is the case? (It will be seen that the aberration effect is equivalent in any one region to a systematic error in the proper motions.) In order to test this, I made use of diagrams constructed as follows: each proper motion whose components are x'', y'' is represented by a dot at the point whose cartesian coordinates are (x, y). These diagrams were made for several of the regions of the Groombridge proper motions. The same diagram will be made to represent the corrected proper motions $x''-u''$, $y''-v''$, by merely shifting the origin to the point (u, v). Thus, by regarding the origin as arbitrary, we can allow for the application of the correction for the aberration effect of any arbitrary acceleration of the Sun. But in the diagrams two features were noticeable: (1) the two streams were conspicuously evident in the distribution of the dots, even when the origin was omitted from the figure altogether; (2) the origin is not really arbitrary, but is fixed with certainty to within about 1″ per century by the tendency of the dots to agglomerate closely about one point, this point being practically coincident with the position of the origin used in drawing the figure.

As regards the feature (1), the recognition of the two streams in a diagram of this kind is perhaps a matter in which individual bias may play some part. If anyone wishes to see for himself a diagram of this kind, reference may be made to Professor Dyson's paper, "The Systematic Motions of the Stars" (*Proc. Roy. Soc. Edinburgh*, vol. xxviii., part iii., p. 232). The diagram 1 is constructed in this way, but the space around the origin (corresponding to the small proper motions) is left blank, whereas for our purpose it should be imagined to be filled with very numerous dots—three thousand at least. I think an examination of that figure will show that no change in the position of the origin can get rid of or in any way

affect the appearance of the two streams, which are so well shown in the distribution of the dots.

As regards feature (2), there can be no difference of opinion in fixing (to within the limits stated) on the point about which the dots aggregate most closely; and the fact that this always coincides approximately with the adopted origin shows that the proper motions in the region are not affected by a systematic error of more than about 1″ per century, whether arising from aberration or from any other causes.

It may be noted that the existence of an acceleration of the Sun great enough to produce an appreciable aberration effect of the kind discussed would be difficult to account for by any distribution of gravitating matter in the universe reconcilable with our present knowledge.

On Some Points with regard to the Light Fluctuation of Variable Stars. A Rejoinder to Mr. H. C. Plummer's Criticisms. By Karl Pearson, F.R.S.

(1) The purport of my original paper "On Some Points with regard to the Light Fluctuation of Variable Stars," *Monthly Notices*, vol. lxix. p. 128, was twofold. In the first place, I desired to draw the attention of astronomers to the new instruments of research put at their disposal by the methods of modern statistics; and in the next place, to indicate that these methods applied to variable star problems suggested not a few lines of observational inquiry, and possibly modification of opinions already formed. My paper concluded with the words: "I will not venture to be dogmatic about a single conclusion or constant given in this memoir. As a statistician, I am painfully conscious of the dangers of small samples. But certain points have, I think, been indicated, which are worthy of the attention of astronomers."

It will be seen that I was fully conscious of the smallness of our present knowledge in this field, and wished my paper to be regarded as one of suggestion. Mr. Plummer's description of it as "the mere accumulation of a mass of uncoordinated material, and the indiscriminate volley firing . . . . of a statistical method," is, I venture to hold, rather too sweeping. I am not prepared to accept the view that even existing material, slender as it is, may not provide valuable results, treated by the new methods, and would cite recent papers by Dr. Charlier, Professor Turner, and Father Stein to confirm my opinion.

The main criticism of Mr. Plummer, however, does not turn on the material used; it turns on a supposed blunder in theory, and is discussed in §§ 3 and 4 of his paper. Had he approached me for an explanation of the supposed paradox, I think a few minutes' conversation would have modified his standpoint, and

saved something of this discussion, or turned it into channels more likely to be of service to our knowledge of variable stars.

I fully admit, however, that to those who come for the first time to the methods of correlation, there must be lacking the experience gained by daily handling of these processes; and one ought to be grateful at the present time to every astronomer who considers the subject worthy of examination at all.

(2) To those who are approaching modern statistical methods for the first time, an illustrative example is often more suggestive than any discussion of abstract theory. I will therefore illustrate Mr. Plummer's position on a definite case. x, z and $y=x-z$ are three variables for which—

Mean x $=422{\cdot}86$	$\sigma_x=20{\cdot}61$
Mean z $=1{\cdot}45$	$\sigma_z=5{\cdot}67$
Mean $x-z=421{\cdot}41$	$\sigma_{x-z}=19{\cdot}45$

with the correlations—

$$r_{z,\,x-z}=-{\cdot}0657$$
$$r_{x,\,x-z}={\cdot}9618$$
$$r_{x,\,z}={\cdot}3357$$

Now, if I asserted that the correlation ·9618 was the fundamental correlation, a critic following Mr. Plummer's line of argument would construct a triangle from σ_x, σ_z, and σ_{x-z}, and reply—

$$r_{z,\,x-z} \text{ must be } > \sqrt{\sigma_x^2-\sigma_z^2}/\sigma_x$$
$$\text{or } >{\cdot}9615.$$

He would thus reach the conclusion that the correlation was spurious to the extent of all but ·0003. He would say that I had overlooked a simple line of criticism. That if ·9618 meant anything at all, it should mean that $x-z$ is almost rigorously a linear function of x. But if this be so, a similar relation ought to hold between x and z. This is obviously not so. Hence he would argue that it is impossible to draw any conclusion of value from the figure found for the correlation, the magnitude of which it would then be suggested is fully accounted for by the simple fact that the value of z is very small in comparison with the value of x. It would then be suggested that in selecting ·9618 as the fundamental correlation, we must have been misled by a want of familiarity with the subject, and had made a not altogether judicious use of our own machinery. It is very clear that if an argument such as I have given above be really correct, we might justly conclude that astronomers would not be attracted by the modern methods of statistics, for they would lead to results from which no useful deduction could be made.

I do not think I have mistaken the nature of the argument used by Mr. Plummer: it is perfectly general, and is applied by

him indifferently to my results for Algol, Cluster, and Long Period Variables, to show that in all these cases the bulk of the correlation deduced by me is spurious.

Now, I think, one illustration such as this will suffice to show that the argument is faulty. In the above case x and $x-z$ measure the length of right and left femur (or upper bone of the leg) in about 100 prehistoric skeletons, and the correlation is certainly not spurious, but a true measure of the relationship between these organs. The correlation between any two parts of the human body varies from 0 to 1, approaching very closely to 1 when the bones are homologous, and being almost zero when we deal with slightly related organs. There is, I think, not a single word in Mr. Plummer's argument which does not directly apply to this illustration, and a little consideration of it will show precisely wherein his misinterpretation of my results lies. Our two bones are independent entities, controlled during development by certain "determinants" which enforce on them correspondence in length.* If we consider them as the *primary* variates, their difference z is a *derived* variate, which is not *a priori* given, but is *a posteriori* determined from their values. In fact, Mr. Plummer's triangle is determined by an angle and two sides; and when he has selected the two variables fixing these, he cannot turn round and take the third side as an *a priori* datum. Given three variables, x, y, and z, such that $y=x-z$, *where we have no knowledge*, we may assume any pair we like as primary, but we cannot then turn round and assert that the correlation found is "spurious." Mr. Plummer was quite at liberty to criticise my choice of derived variate, but he has then to show that another choice is more consonant with existing astronomical knowledge. His paradox, that the correlation between maximum light and light range *must* be largely spurious, is based on a misinterpretation of the theory of correlation. He is assuming that a triangle which requires only three elements to determine it has *a priori* four elements given. His argument would make every high correlation spurious, because if x and y are correlated by assuming $x-y$ as a datum, we could prove that x and y *must* be to a larger or smaller extent correlated.

But there are other points in which it is desirable to criticise Mr. Plummer's statements, or they may some day pass as theoretically correct. He says (p. 352) that the simple fact that z is very small as compared with x fully accounts for the high correlation observed. Again, a practical illustration will be of value: let the reader find the correlation for the two following cases:—

I.	$x=$	300,	400,	500,	600,	700,	800,	350,	450,	550,	650
	$z=$	3,	4,	5,	6,	7,	8,	3·5,	4·5,	5·5,	6·5
II.	$x=$	300,	400,	500,	600,	700,	800,	350,	450,	550,	650
	$z=$	5·5,	7,	5,	8,	4,	6·5,	3·5,	4·5,	6,	3

* In precisely the same manner for the eclipse variables, L_2 measuring maximum light and L_2-L_1 measuring the amount cut off by the eclipsing

He will soon convince himself that relative size is not what affects correlation. The whole of the correlation formulæ depend on *variability*, and not on absolute size, and this is a well-known law of statistics. Correlation is a relation between deviations from the mean, and not absolute sizes. It would be quite possible, by the simple process of mixing the femurs from different skeletons, to get zero correlation between right and left limb, but the relative size of x and z would still be 422·86 and 1·45.

There is a second statement, however, in Mr. Plummer's criticism which needs correction from the statistical standpoint, and is of much importance for a later argument. He says that if x be nearly a linear function of $x-z$, then it follows that a similar relation ought to hold between x and z. This clearly, however, does not hold in the case of the right and left femur, where the correlation has dropped from ·96 to ·33; nor, again, in the case of z and $x-z$, where the correlation has actually become insignificant and negative. Yet there is undoubtedly a close linear relationship between x and z. Mr. Plummer's statement cannot, therefore, be a universal truth. Now the curious part of the whole matter is that for the Algol stars x and z are really highly correlated. Hence either his statement is correct, in which case the whole of his criticism falls to the ground in the case of the Algol stars—and this in itself proves that his treatment of spurious correlation is inadequate, for he applies it to those stars—or the statement is incorrect, and this emphasises the fact that we have to proceed with caution when dealing with statistical theory. There is, I think, no doubt that it is incorrect; and, without handling large numbers of coefficients of correlation, a little study of Mr. Plummer's triangle indicates that if σ_x be equal or nearly equal to σ_{x-z}, then we have closely

$$r_{x,z} = -r_{z,x-z} = \sqrt{\tfrac{1}{2}(1-r_{x,x-z})},$$

and both approach the value *zero* when $r_{x,x-z}$ is nearing unity. In other words, as shown by the organic correlations of the bones of the skeleton, we can have very high correlations of two quantities, and moderate or very small correlations of either or both with their difference.

(3) As I have indicated in the previous section, I feel compelled to differ from Mr. Plummer as to three fundamental statements bearing on statistical theory made in his paper: (*a*) that when a correlation between two quantities is high, the correlation between their difference and either must be high if the relationship is to have significance; (*b*) that it is at all possible to account for the high correlation between two quantities, still less fully account for it by the fact that one is very small compared with the other; and (*c*) that it is possible to demonstrate that in a high correlation

body are independent entities controlled to close relationship by the causes producing the sizes of primary and secondary and of their orbit. The appearance of L_2 in both is not a sign of spurious correlation: see my footnote, *M.N.*, lxix. p. 131.

a large amount is spurious by means of the "triangle" proof provided by Mr. Plummer. This proof completely overlooks the distinction between primary and derived variates in the theory of correlation. The correlation of the primary variates is the fundamental datum, the variability of the derived variate a resulting fact. Had the correlation between x and z not been what it is, then σ_{x-z} would not be what it is. We cannot, *a posteriori*, turn round and assert that correlation must exceed a certain value because σ_{x-z} has its deduced value.

Let me emphasise this by an illustration which in one sense may be suggestive to the astronomer. I find by experiment that when A and B make observations under the same conditions, their judgments are not independent but correlated; the individual environment of each observation influences their judgments in the same manner. Now if x be the error of A and y of B, and σ_x, σ_y the variabilities of the two observers, their personal equation is $x-y$ and its variability σ_{x-y}. But σ_{x-y} is not equal to $\sqrt{\sigma_x^2+\sigma_y^2}$, as it should be if their judgments were independent. There is a correlation r_{xy} between their judgments, and

$$\sigma_{x-y}=\sqrt{\sigma_x^2+\sigma_y^2-2\sigma_x\sigma_y r_{xy}}.$$

Now Mr. Plummer's argument in a case like this would amount to saying that r_{xy} *must* exceed a certain value because we can construct a triangle out of σ_x, σ_y and σ_{x-y}. There is not any indication throughout Mr. Plummer's paper that he was in the least conscious that *one* side of his triangle was a result of his primary data, and could not possibly be used as a given quantity to determine limitations in value for the other primary variables. It is stated in Mr. Plummer's paper—and this point was chiefly emphasised when the paper was read—that I had overlooked spurious correlation to the extent of all but ·0001 in ·9996. Had Mr. Plummer said, "Professor Pearson has chosen the wrong primary variates," he would not have placed himself in opposition to fundamental principles of statistical theory. He would not then have assumed me to be overlooking a familiar idea in statistics. But he would have had to justify in each instance his choice of different primary variables.

(4) I did not, however, select my primary or derived variables in the least at random. I had before me, in each case, the full results, and selected, after due consideration, the most reasonable primary variables as they appeared to me in our existing state of knowledge. I am glad that Mr. Plummer's criticism allows me to say more on this point. A few words on the history of the idea in the paper may perhaps throw light on the matter. I have been for some time investigating the value of V_d, namely, the proportion that the variability in distance of the stars from us bears to their mean distance. It is a stellar constant which can be found from other than parallax determinations, and is obviously of great importance in testing the random or non-random distribution of the stars in space. One of the methods of determining the value

of V_d which occurred to me was from the maximum and minimum light of variable stars. These are phenomena which occur at the same distance, and we should therefore naturally expect a very high correlation between L_1, L_2, and $L_2 - L_1$, due solely to their common distance. *A priori*, we should expect *not a low, but a very high correlation between any two of these three quantities.* I had hoped to reach from it another estimate of V_d. As a matter of fact, I found that there must be considerable relationship between the actual amounts of light emitted at maximum and minimum, and that these largely modified the high correlation naturally to be expected owing to common distance. The fact that I was really seeking V_d will throw light on a good deal of the analysis of the paper. The prominent point however remains, that, *a priori*, we should not expect, as Mr. Plummer apparently does, very low, but on the contrary high correlations between any pair of our three variates.

Let us start with the Algol stars. Mr. Plummer holds that the high correlation observed is nearly all spurious: "Even in the case of the Algol variables, the figures not only prove that the correlation need not be particularly large, but even suggest that it is surprisingly small" (Plummer, p. 352). Now this statement can only be based on the fallacious triangle argument. Given my choice of variables, however, that falls to the ground. Or, if we pass to my own position that the choice of another pair of variables might modify the answer to be given, which pair would Mr. Plummer have selected? Let $R = L_2 - L_1$, L_2 being the maximum, L_1 the minimum light. Then, of the three quantities R, L_2, L_1, two are the primary variates, the third the derived variate. I selected, following the current theory of Algol variables, R the measure of the obscuring portion of the eclipsing body, and L_2 the full light of the primary star, as my fundamental variates,—as the measures of the quantities which have ultimately separate, if correlated, physical origins. The correlations I had before me were—

54 *Stars.*	57 *Stars.*
$r_{RL_2} = \cdot 9837 \pm \cdot 0030$	$r_{RL_2} = \cdot 9959 \pm \cdot 0007$
$r_{RL_1} = \cdot 8727 \pm \cdot 0219$	$r_{RL_1} = \cdot 9680 \pm \cdot 0056$
$r_{L_2L_1} = \cdot 9499 \pm \cdot 0090$	$r_{L_2L_1} = \cdot 9866 \pm \cdot 0024$

As I have said, only two of these are variates with independent physical origin. I chose the two with the highest correlation, partly because they had the highest correlation, because, *a priori*, that is what we should expect, and partly because they are the pair indicated by the current theory of Algols. It would be instructive to hear which pair Mr. Plummer would select as of negligible correlation, having regard to their probable error, and leading to the "spurious correlation," he says, exists between R and L_2. A noteworthy point is that they fulfil the very condition laid down by him—which however is, I think, incorrect—that if the relationship between R and L_2 is nearly perfect, that between the other

pairs should be so also if the matter is to mean anything at all. Of course the statistician who has had to deal with many series would not select, *a priori*, out of three variables, x, z and $y = x - z$, the pair with the *lowest* correlation, as *ipso facto* representing the primary variates. Such a case as the left and right femur would lead him at once to see the error of his ways. But had Mr. Plummer applied such a method to the Algol stars, he must have concluded that r_{RL_1} was ·87 to ·97 in magnitude, and he could not, I think, have written the sentence, "the figures not only prove that the correlation need not be particularly large, but even suggest that it is surprisingly small" (p. 352). Any handling of the figures shows, on the contrary, that the correlation must be surprisingly large.

I venture to hold that my choice of primary variates was the correct one, because no other theory than the eclipse theory has at present any claim to attention. When it has, I shall be quite prepared to change my primary variates, but the figures above given demonstrate that it will need no sensible modification in my conclusions as to the Algols. Mr. Plummer's suggestion (p. 352), that it is unnecessary to follow me in the inferences I have based on the large value found for r_{RL_2}, is, I think, penned without due consideration of (*a*) which pair of variates he assumed to be primary, (*b*) why he supposed physically that their correlation was low or zero.

There is another point, however, which is worth noticing once for all: the results reached enable us with a close degree of accuracy to predict $L_2 - L_1$, L_1 or L_2 from a knowledge of any one of them in the case of the Algols. I do not think that before my paper this fact was recognised by the bulk of workers on Algol variables.

(5) I now pass to the Long Period Variables, merely remarking that the charge that the bulk of the ·9996 correlation is spurious falls at once to the ground if we accept the choice made of primary variates. In this series we have for the 79 stars—

$$r_{RL_2} = \cdot 9996 \pm \cdot 0001$$

$$r_{RL_1} = \cdot 4237 \pm \cdot 0623$$

$$r_{L_2L_1} = \cdot 4506 \pm \cdot 0625$$

The first point to be noted is, that in every case the correlation is very significant as compared with its probable error. There is not the least ground for asserting that r_{RL_2} is so large because there is no correlation between L_1 and either R or L_2. If I had accepted the view that star-spot maximum was to be associated with star-light maximum, I should still have indicated, for the first time, a very sensible relationship between the amount of star-spots and the minimum light of the star. I did not select R and L_1 as primary variates: (*a*) because, owing to the distance factor, I anticipated high, not low, correlations in these cases; (*b*) because the magnitudes are *photometric*, and I am not convinced that a large area of sun-spots would indicate increased illumination, although it might

undoubtedly indicate increased radiation of certain types;* (*c*) because the increased illumination due to those star-spots has on an average to be 37 times as great as the normal illumination of the star. I hardly think this jump from what we know of the Sun and its spots to what we have to predicate of the stars is at present justifiable. And lastly, and mainly, (*d*) because obscuration of some sort, whether by a secondary body, a variable atmosphere, a tenuous medium, or what not, seems to be the one sort of general idea which might give a common source to the variability of the various classes of variable stars. Mr. Plummer, curiously enough, used the following words in his criticism, with which I heartily concur:—

"If we consider the light curves for the Algol and the Antalgol types, we might expect to find some analogous features in the causes underlying the two classes; by accepting the eclipse theory of the former, we apparently exclude such a possibility" (p. 350).

Now the one point of statistical agreement between the three types of variables I have dealt with is the high correlation between light range and maximum light. If these two are accepted as the primary variates, then it is possible to find some analogous features in the causes underlying our different classes. The other correlations show no such agreement. We are justified, in the present state of astronomical knowledge, in seeing first where the general principle of obscuration as a source of light variation leads us. To adopt it until it is shown to be erroneous is merely to apply Ockham's razor. At any rate, it is the one feature of agreement between the various types; and if Mr. Plummer wishes to discard it, he is bound to account for the high correlation between range and maximum light by three different causes in the three different classes of stars; for the low correlation between R and L_1 in the cluster variables will not account for the state of affairs in either the Algol or Long Period variables, as I have just shown.†

But there is another purely physical point which I think Mr. Plummer has overlooked, and which is obvious on a consideration of my diagram for the Long Period variables, vol. lxix. *Monthly Notices*, p. 148. There is no *general* physical reason (such as want of correlation) for all the stars being clustered along a line, for there are at least eight which fall markedly off that line. And if eight, why not more? If the result were merely the outcome of a statistical process, all the stars ought to fall on to the line. The

* It would be interesting to know whether there are any comparable visual and photographic measurements of long period variables which might throw light on this point.

† Mr. Plummer writes on p. 350: "But if one of them r (x, y) is *small*, which will be the case if x and y be in no way related, then . . . . one at least of the other correlation coefficients will exceed numerically . . . 0·707. This explains how quite a large coefficient can be obtained which is wholly spurious." From my standpoint this statement is incorrect; but if we admit it, Mr. Plummer ought to have shown that one or other correlation for the Algol and for the Long Period variables was zero. His omission of this stage in his proof—which cannot be provided—shows that he was unaware of the values of the remaining correlations.

fact that some, the majority, do, and others do not, suggests forcibly to my mind that there is a physical reason for the bulk falling on the line, and the eight stars failing to do so. In other words, the treatment has brought out what had not, as far as I am aware, been previously noticed—a real source of differentiation in the Long Period variables.

(6) Turning to the Cluster Variables, I have indicated in the previous paragraph why I chose range and maximum light as my primary variates. But a word more must be said about these, because they are the sole case in which one of the correlations is possibly insignificant, having regard to its probable error.

In this case we find—

$$r_{R,\,L_2} = \cdot 9283 \pm \cdot 0098$$
$$r_{R,\,L_1} = -\cdot 1269 \pm \cdot 0696$$
$$r_{L_1 L_2} = \cdot 2512 \pm \cdot 0662$$

We now reach a point at which I wish to be very emphatic. Is it reasonable to suppose that there is no relation at all between R and L_1, between range of light and minimum light; and is such an absence of correlation *a priori* probable and more reasonable to start from than the hypothesis of a high correlation between range and maximum light? I contend that it is almost inconceivable that $r_{R,\,L_2}$ should be high, solely because there is no relation between R and L_1. What one means when one says that there is no relation between minimum light and the additional illumination which gives maximum light is undoubtedly that the light-giving properties of the star and the additional source of illumination are independent. But in reasoning on this, one forgets too often that these light-giving properties are reduced for us by the inverse square of the distance d. In other words,

$$R = \frac{\lambda}{d^2} \text{ and } L_1 = \frac{\lambda_1}{d^2},$$

where λ and λ_1 are total luminosity constants, and we really mean that λ and λ_1 are uncorrelated.

Now we easily find

$$r_{R,\,L_1} = \frac{r_{\lambda\lambda_1} V_\lambda V_{\lambda_1} - 2V_d(V_\lambda r_{\lambda d} + V_{\lambda_1} r_{\lambda_1 d}) + 4V_d^2}{V_{L_2 - L_1} V_{L_1}}.$$

Hence if the light-giving properties of the star are unrelated, as seems probable, to their distances from us, and depend only on their own physical constitution, we must have

$$r_{R,\,L_1} = \frac{r_{\lambda\lambda_1} V_\lambda V_{\lambda_1} + 4V_d^2}{V_{L_2 - L_1} V_{L_1}}.$$

This is an essentially positive quantity, and cannot be zero unless $r_{\lambda\lambda_1}$ is *negative*. In other words, the assertion that $r_{R,\,L_1}$ may reasonably be anticipated to be zero means, not that the luminosities

of the star and of the addition are independent, but that they are *negatively* correlated, and that this relationship is somehow connected with V_d, a positional constant. This may be the actual state of affairs, but it is not, *a priori*, a reasonable assumption to make to guide our choice of primary variates. What Mr. Plummer really supposes is, I think, that $r_{\lambda\lambda_1}$ is zero, and this leads to—

$$r_{R,L_1} = 4V_d^2/(V_{L_2-L_1}V_{L_1}).$$

This was my starting-point for discovering the parallax variability V_d. But we see that it always involves a *positive* value for $r_{R,L}$. It could not possibly come out negative, as in the case of the Cluster Stars, and could not be zero unless all the variable stars were practically at the same distance from us. Actually, with the data at our command, we might, *a priori*, expect it to have a large or even impossible value instead of zero.* We only get a low value of r_{R,L_1} by the hypothesis that the stars with a *low* normal luminosity have a *large* periodic addition to their light. This is probably, as our numbers show, true for the Cluster stars, but it is not *a priori* obvious. To assume, therefore, that r_{R,L_1} is zero because it is reasonable to suppose R and L_1 independent is not nearly as justifiable as assuming that our independent variates, whatever they are, have high correlation. The lowness of the correlation is not the obvious result; it is the mystery which has to be explained.

(7) There is still a point where I must express my divergence from Mr. Plummer. He desires to defend magnitudes as against amounts of light, and to advocate the use of magnitudes in an inquiry of this kind. He remarks that one is a function of the other, and that luminosity is liable to all the errors of determining magnitude. I was not unaware of this, and indeed my environment rather leads me to over- than under-emphasise the difficulties

* For the Cluster Stars, $V_{L_2-L_1} = \cdot4237$ and $V_{L_1} = \cdot1984$. For the Long Period Variables, 87 stars, $V_{L_2-L_1} = 1\cdot204$ and $V_{L_1} = 3\cdot520$; for the 79 stars, $V_{L_2-L_1} = 1\cdot215$ and $V_{L_1} = 1\cdot495$. Hence in the three cases respectively we have, if $r_{\lambda\lambda_1} = 0$,

$$r_{R,L_1} = 45\cdot6V_d^2,\ \cdot94\ V_d^2 \text{ and } 2\cdot2V_d^2.$$

Now the value I will cite at present for V_d is $1\cdot44$, deduced from the Yale observations, and this asserts that the difference of the distances of the stars from us is of the order of their distance from us. Clearly this would give impossible values of r_{R,L_1} if applied to the Long Period Variables. There is little doubt that $r_{\lambda\lambda_1}$ must have a substantial *negative* value. In the case of the Cluster Stars V_d must be very much smaller—its probable value can only be ascertained when we know the parallax of a star in the cluster. But no value of V_d can make r_{R,L_1} negative. That must be a result of $r_{\lambda\lambda_1}$ being negative. This is probably true, but it is not, *a priori*, to be anticipated, and I think I may safely say that it is not what Mr. Plummer means when he thinks it reasonable that r_{R,L_1} should be zero. I believe him to be thinking of the vanishing of $r_{\lambda\lambda_1}$, *i.e.* independence of the luminosity properties of the normal star and of the light addition, which is quite a different point, and should lead him in Algol and Long Period Variables to anticipate a high value for his correlation, not a zero value, and a positive, not a negative value for the cluster stars.

of accurately determining magnitude.* It does not, however, follow that because the logarithm of energy is subject to all the errors of determining energy, and is itself a function of energy, that we should get the best results if it were used in the equations of mechanics. Mr. Plummer's illustration from the cluster variables that

$$r_{m_2,\, m_2-m_1} = \cdot 7540$$

is an excellent illustration of my point. He writes: "The apparent correlation is much less than that which results from the luminosities, but the certainly spurious element is also much less, so that room is left for the effect of a small but possibly real correlation" (p. 352).

Now I have indicated above that if we start with L_2 and $L_2 - L_1$ as our primary variates, there is in $r_{L_2,\, L_2-L_1}$ no spurious correlation. Let us now investigate what is the spurious correlation in this magnitude result.

Mr. Plummer is obviously correlating

$$-\log L_2 \text{ and } -\log (L_2/L_1),$$

that is to say, is correlating functions of L_2 and L_2/L_1.

Now, in the first place, I observe that Mr. Plummer, without any warning on the point, is asking us to correlate two quantities, m_2 and $m_2 - m_1$, of a wholly different physical character; for his first function involves the distance of the star, and his second function is wholly free from the distance factor, and is in fact a mere number.† My investigation concerns itself with the *same* physical quantity for the star under different conditions; the physical unit of both my variates is the same.

But there is a far greater difficulty to be considered. The variates are R, L_2 and L_1; and although, in my opinion, R and L_2 are the primaries, Mr. Plummer appears to prefer R and L_1, and, perhaps, somebody else may assert that L_2 and L_1 are so to be considered. But whichever pair be selected, the corresponding correlation is free of all spurious correlation.

Let us take these possibilities in order.

(i) R and L_2. Mr. Plummer is correlating functions of L_2 and $L_2/(L_2 - R)$, or of L_2 and R/L_2. Hence if we sorted our light ranges at random and distributed them among the variable stars, there would still be correlation. If the light range were constant, there would be perfect correlation.

* Mr. Plummer suggests that I have overlooked the fact that visual magnitude can be determined by photographic methods. I do not see that this is to the point if the suggestion were correct; the sensation of vision might be itself photographic in character without upsetting my point that luminosity is a simpler character than magnitude in the relations I am concerned with, and leads to simpler and, as shown above, safer results.

† His first quantity involves the units of (*a*) intensity of illumination, (*b*) superficial area, and (*c*) stellar distance. His second quantity, which he correlates with this complex physical quantity, involves no physical units at all, but is a pure ratio.

(ii) R and L_1. Mr. Plummer is really correlating $L_1 + R$ and R/L_1. Hence if we sorted our light ranges at random among the stars there would still be correlation, which would be perfect if the light range were constant.

(iii) L_1 and L_2. Mr. Plummer is really correlating L_2 and L_2/L_1. Hence if we sorted our minimum luminosities at random among the stars there would still be correlation, which would be perfect if the minima were all equal. As an illustration of the amount of spurious correlation involved in r_{m_2, m_2-m_1}, let us take the Case (ii) with R and L_1 primary variates. There is no spurious correlation in r_{R, L_1} but if the ranges be distributed at random among the stars there is still ·70 of "spurious correlation" in the true sense left.* Again, take Case (i). I find the spurious correlation in r_{m_2, m_1-m_2} is *negative* and over ·4; we can therefore conclude that r_{m_2, m_1-m_2}, as given by Mr. Plummer, = ·75, must much *underestimate* the true correlation; for if there was no relation between L_2 and R at all, this correlation would be $-$·4. Actually I have shown that the relationship is very much greater, *i.e.* ·93. Here the luminosities indicate a truth disguised by the magnitudes.

The lesson of these results is, I think, pretty clear. Mr. Plummer considers that I have overlooked a large amount of spurious correlation, and that there is preconception on my part in using luminosities as against magnitudes. He considers that his magnitude correlation is less liable to these defects than my luminosity correlation. I have shown above that for my choice of variables there is no spurious correlation, but that whatever choice of variables be made, there will be spurious correlation in his magnitude correlation.

(8) Lastly, I would add one word as to a criticism made by Mr. Plummer (p. 353): "The 'ready explanation' which Professor Pearson suggests without formulating, and then criticises, has not occurred to me, and it does not seem to require two or three pages of mathematical reasoning to see that the increase of light fluctuation with period is altogether surprising, if it be real."

I feel fairly convinced that the evidence shows it to be real. I am sorry if Mr. Plummer considers the explanation, which seems to me fairly concise, on p. 142 (namely, that if we give the dark body a mean constant size, both period and fluctuation would decrease or increase together), is insufficient for the reader. Actually the suggestion was made to me by Professor Turner, and seemed to me so reasonable and probable that I worked it out at length, for I held, and still do, that it requires careful consideration. Had it been workable, it would have accounted at once for this relation of period and fluctuation. Of Mr.

* The formula for the spurious correlation is $r_{m_2, m_1-m_2} = \sin(\theta - \phi)$, where $\tan\theta = V_{L_2-L_1}/V_{L_1}$ and $\tan\phi = \sigma_{L_1}/\sigma_{L_2-L_1}$. On the general subject of spurious correlation, see my paper, which first defined the term, *Roy. Soc. Proc.*, vol. lx. pp. 489–98, 1897.

Plummer's rival theory on p. 354, I will only say now that it was hardly needful to propose it if he doubted the reality of the result.

In conclusion, I would remark that some good may have come from this controversy if it has provided an opportunity for drawing attention to one or two fundamental points in statistical theory, and to possible directions of inquiry in the case of variable stars of the different classes discussed in my paper. I should particularly like to have some additional information with regard to the outlying stars in my third diagram (p. 148).

The Long Period Variable RT Cygni (*Ch.* 7085) *in* 1908.

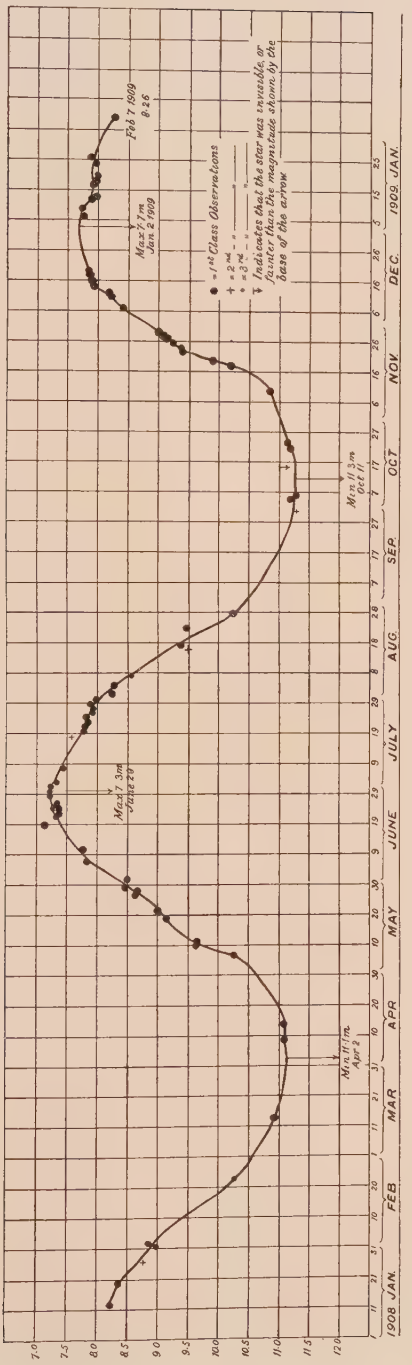
By A. N. Brown. (Plate 21.)

The following 69 observations of this Variable made in 1908 with 10 belonging to 1909 cover two maxima and two minima, the probable dates of which are shown on the curve appended. Owing, however, to continued bad weather during the second half of December, considerable uncertainty is inevitable with regard to the last maximum. The dates of maximum and minimum light are assumed to be those on which a smooth curve drawn through the observations reaches the highest and lowest points respectively.

In the 1st. column below the date is given, and in the 2nd. the Julian date corresponding, omitting the constant number 2410000. In the 3rd. column T indicates a 5-in. refractor, t a 3-in. refractor, each of these letters being followed by the magnifying power used. The 4th. column shows the value attached to each observation, 1 denoting good, reliable; 2 fairly good—the Moon, thin clouds, dew on the lens, etc., having been some hindrance; 3 a poor estimate. Most of the comparisons following in the 5th. column were made by the "fractional" method, but each has here been expressed in steps, the value of a step in all cases being $\frac{1}{10}$ magnitude. All the comparison stars used are numbered as in Hagen's Atlas, the negative sign after the comparison star implying that the variable is fainter, and the positive sign brighter, than that star. The last column gives the magnitude deduced from the comparisons, a mean being taken when two or more separate light-estimates are made. In working out these results the Harvard value of each comparison star has been adopted where this was forthcoming; when the H.C.O. does not assign a value to one of Hagen's stars used, Hagen's own value, as given in the *Atlas Stell. Var.*, has been taken.

The Observations.

Date.	Julian date.	Instr.	Class.	Comparisons.	Ded. mag.
1908.					
Jan. 12	7953	t. 30	1	5 − 4·5, 10 + 1 ; 7 − 2·5, 10 + 1	8·3
20	7961	T. 50	,,	= 10	8·4
27	7968	t. 30	2	14 − 1	8·8
Feb. 1	7973	T. 50	1	15 − 1·5, 20 + 3·5 ; 16 − 3·5, 19 + 2·5	9·0
2	7974	,,	,,	15 − 1, 20 + 3·5 ; 16 − 1·5, 19 + 1·5	8·9
23	7995	T. 95	3	41 + 1	10·3
Mar. 14	8015	T. 200	1	43 − 3·5, 44 + 0·5	11·0
April 8	8040	t. 120	,,	44 − 1	11·1
13	8045	t. 150	2	44 − 1	11·1
May 6	8068	T. 95	1	22 − 8, 38 + 1·5	10·3
9	8071	,,	,,	23 − 1, 25 + 0·5	9·6
10	8072	,,	,,	23 − 1·5, 25 + 0·5	9·7
18	8080	T. 50	,,	15 − 4, 20 + 1	9·2
21	8083	,,	,,	15 − 1·5, 20 + 3·5 ; 16 − 4, 19 + 2	9·0
26	8088	,,	,,	10 − 2·5, 15 + 2	8·6
27	8089	t. 30	,,	13 − 0·5, 14 + 0·5 ; 12 − 2, 15 + 1	8·7
28	8090	T. 50	,,	10 − 1·5 ; 10 − 0·5, 15 + 4	8·5
31	8093	T. 25	,,	10 − 1·5, 14 + 1 ; 11 − 1	8·5
June 6	8099	t. 30	,,	4 − 2, 6 + 1 ; 5 + 1	7·8
10	8103	T. 25	,,	4 − 0·5, 5 + 1	7·7
18	8111	t. 30	,,	3 − 5, 4 + 5	7·2
21	8114	,,	,,	3 − 7, 4 + 3	7·4
22	8115	T. 25	,,	3 − 7, 4 + 2·5	7·4
23	8116	,,	,,	3 − 7, 4 + 2·5	7·4
24	8117	t. 30	,,	3 − 6·5, 4 + 3	7·3
25	8118	,,	,,	3 − 7, 4 + 3	7·4
28	8121	,,	,,	3 − 6, 4 + 4	7·3
29	8122	,,	,,	3 − 6, 4 + 4	7·3
30	8123	,,	,,	3 − 6, 4 + 4	7·3
July 2	8125	,,	,,	3 − 7, 4 + 3	7·4
7	8130	T. 25	,,	3 − 8, 4 + 2	7·5
17	8140	t. 30	2	4 + 0·5 ; 3 − 8·5, 4 + 1	7·6
19	8142	,,	1	4 − 1·5, 6 + 1	7·8
20	8143	t. 30	1	4 − 1·5, 6 + 1	7·8
22	8145	,,	,,	5 − 0·5, 6 + 0·5	7·9
23	8146	,,	,,	5 − 0·5, 6 + 0·5	7·9
25	8148	,,	,,	5 − 1, 7 + 0·5 ; 6 − 0·5	7·9
26	8149	T. 50	,,	5 − 1·5, 7 + 0·5	8·0
28	8151	t. 30	,,	5 − 1, 7 + 1	7·9
29	8152	t. 60	,,	= 7	8·0
31	8154	T. 50	,,	7 − 2·5, 10 + 1	8·3


Max 7.1m Jan 2 1909
Feb 7 1909 8.2s
Max 7.3m June 20
Max 7.1m Apr 3
Max 11.3m Oct 11
= 1st Class Observations
+ = 2nd " "
• = 3rd " "
↓ Indicates that the star was invisible or fainter than the magnitude shown by the base of the arrow
1908 JAN. FEB MAR APR MAY JUNE JULY AUG. SEP OCT NOV DEC. 1909 JAN.
7.0 7.5 8.0 8.5 9.0 9.5 10.0 10.5 11.0 11.5 12.0

LIGHT CURVE OF RT CYGNI IN 1908.—A. N. BROWN.

The Observations—continued.

Date.	Julian date.	Instr.	Class.	Comparisons.	Ded. mag.
1908.					
Aug. 3	8157	t. 30	,,	7 − 3, 10 + 1	8·3
6	8160	t. 60	,,	10 − 1·5, 14 + 1·5	8·5
15	8169	t. 75	2	= 22	9·5
16	8170	,,	1	19 − 1, 22 + 1	9·4
22	8176	t. 60	,,	= 22, = 23	9·5
27	8181	t. 75	,,	41 + 2 ; 22 − 8, 43 + 3	10·3
Sept. 30	8215	T. 150	2	44 − 3	11·3
Oct. 4	8219	,,	1	44 − 2	11·2
5	8220	,,	,,	44 − 3	11·3
15	8230	T. 200	...	< 44. Var. glimpsed	< 11·0
21	8236	,,	1	44 − 2	11·2
23	8238	,,	,,	44 − 1·5	11·2
Nov. 9	8255	T. 167	,,	43 − 2·5, 44 + 1·5	10·9
17	8263	T. 95	2	41 + 2	10·2
19	8265	,,	1	25 − 2, 30 + 1	9·9
22	8268	T. 70	,,	19 − 1, 22 + 1 ; 23 + 1	9·4
23	8269	,,	,,	19 − 1·5, 22 + 0·5 ; 23 + 1·5	9·4
25	8271	T. 50	,,	15 − 4, 20 + 1 ; 16 − 5, 19 + 1 ; 22 + 2	9·2
26	8272	,,	,,	15 − 4, 20 + 1 ; 16 − 4, 19 + 2	9·2
27	8273	,,	,,	15 − 3·5, 20 + 1·5 ; 16 − 3·5, 19 + 2·5	9·1
28	8274	,,	,,	15 − 1·5, 20 + 3·5 ; 16 − 3·5, 19 + 2·5	9·0
Dec. 6	8282	,,	2	10 − 1, 14 + 2·5	8·5
9	8285	,,	1	5 − 4, 10 + 1·5 ; 7 − 2, 10 + 1·5	8·2
10	8286	t. 30	,,	5 − 4, 10 + 1·5 ; 7 − 2, 10 + 2	8·2
13	8289	,,	,,	5 − 1·5, 7 + 0·5	8·0
15	8291	,,	,,	5 − 1, 7 + 0·5	7·9
17	8293	T. 50	,,	5 − 0·5, 7 + 1·5	7·9
18	8294	t. 30	,,	5 − 0·5, 7 + 1·5	7·9
1909.					
Jan. 5	8312	t. 30	1	4 − 1·5, 5 + 0·5 ; 4 − 2, 6 + 1	7·8
8	8315	,,	,,	4 − 1·5, 6 + 1 ; 5 + 1	7·8
11	8318	,,	,,	5 − 1, 7 + 1	7·9
12	8319	,,	,,	5 − 1·5, 7 + 1	7·9
16	8323	,,	,,	5 − 1, 7 + 1	7·9
17	8324	,,	,,	5 − 1·5, 7 + 0·5	8·0
19	8326	,,	,,	5 − 1·5, 7 + 1 ; 6 − 1, 7 + 0·5	8·0
25	8332	T. 50	,,	5 − 1·5, 7 + 0·5	8·0
27	8334	t. 30	,,	5 − 1·5, 7 + 1 ; 6 + 1	7·9
Feb. 7	8345	T. 50	,,	7 − 2·5, 10 + 1	8·3

The Comparison Stars used.

Hagen's number.	Magnitude. H P.	Magnitude. Hagen.	Hagen's number.	Magnitude. H P.	Magnitude. Hagen.
3	6·67		16	8·71	
4	7·64		19		9·3
5		7·8	20		9·3
6		7·9	22		9·5
7		8·0	23		9·5
10	8·39		25		9·7
11		8·4	30		10·0
12		8·5	38	10·43	
13	8·54		41		10·4
14	8·67		43		10·6
15		8·8	44		11·0

New Barnet, Herts:
May 1909.

Results of Micrometer Measures of Double Stars made with the 28-inch Refractor at the Royal Observatory, Greenwich, in the year 1908.

(*Communicated by the Astronomer Royal.*)

The measures were made with a bifilar position-micrometer on the 28-inch refractor, focal length 28 feet. The power generally employed was 670. When bright stars were observed a blue glass shade was usually employed to diminish the light and irradiation. The observations were made in variously coloured fields, or in a dark field with illuminated wires. The initials in the last column are those of the observers, viz.—

S.E.	Mr. Eddington.	L.	Mr. Lewis.	B.	Mr. Bryant.
W.B.	Mr. Bowyer.	H.F.	Mr. Furner.	J.S.	Mr. Storey.

In general the present list of measures is confined to stars of which the separation is under 4″, or which show orbital motion. The complete measures with details will be published in the Greenwich volume for 1908.

The stars observed which do not appear in this list are :—

Σ 42	Σ 1300	Σ 1909	Σ 2272 Aa	Σ 2481 AC	Σ 3078
61	1311	1934	Ac	2505	3083
180	1379	1946	Ad	2527 AC	3086
205	1426 AC	1952	Ae	2524	
412 AC	1447	1964 A & BC	Ag	2522	
645 AC	1461	1965	2364	2585 AC	
719 AC	1463	2007	2379 AB	2824 AC	
753 AC	1487	2087	2379 AC	2895	
915	1511	2094 AC	2426	2978	
1196 AC	1555 AC	2109	2453	3006	
1196 BC	1561	2145 AC	2458	3042	
1224					
1263	1619		2459	3076	

Hough—26, 29, 89, 269, 310 AC, 314 AB, 314 AC, 412, 449, 451, 465, 551, 570, 586, 616.

OΣ—289, 301, 310 AC, 320, 328, 346, 388 AC, 509, 547.

Burnham—136, 137 AC, 141 *c*D, 145 AC, 441, 651, 909, 917, 1315*c*D.

Hussey—150, 485, 576, 602, 805 AC.

Aitken—350, 1200

Howe 32; Küstner 51; Weisse 31 AB and 31 AC; A.G. 134 AC, 214 and 231.

Micrometric Observations of Double Stars at the Royal Observatory, Greenwich.

Star's Name.	R.A. 1910. h m	N.P.D. 1910. ° ′	Position Angle. °	Distance. ″	No. of Nights.	Mags.		Epoch 1908	Obs.
Σ 3056 ...	0 0	56 14	146·9	0·67	4	7·4	7·4	·477	W.B.
β 862 ...	0 0	52 20	131·8	0·66	1	8·5	8·8	·047	W.B.
Σ 3060 ...	0 1	72 25	119·5	3·49	2	8·5	8·7	·745	W.B.
Hu. 1001 ...	0 2	55 54	182·8	1·69	1	8·2	11·2	·027	H.F.
Hu. 401 ...	0 2	66 44	206·7	0·82	1	9·1	9·5	·857	L.
Küstner 3 ...	0 3	70 1	90·1	1·15	1	9·9	9·9	·022	W.B.
*	0 3	70 1	47·2	2·89	2	9·0	10·0	·015	W.B.
Hu. 405 ...	0 12	65 56	274·7	0·90	1	9·3	9·5	·027	H.F.
Küstner 4 ...	0 12	68 43	130 6	2·23	1	9·5	10·1	·660	W.B.
β 779 ...	0 23	66 55	260·1	0·72	2	8·5	9·0	·015	W.B.
Hu. 1009 ...	0 26	57 5	240·8	1·74	2	9·0	9·6	·015	W.B.
Hu. 1010 ...	0 30	56 39	87·7	1·41	2	9·2	9·2	·015	W.B.
Ho. 212 ...	0 31	94 5	85·0	0·25	1	6·0	6·0	·901	B.
Hu. 410 ...	0 32	68 28	315·0	3·12	2	9·0	11·0	·015	W.B.
Σ 59 ...	0 43	39 3	147·5	2·25	3	7·2	8·1	·060	W.B.
Σ 67 ...	0 47	79 53	2·4	1·72	2	8·3	9·0	·444	W.B.
Σ 73 ...	0 50	66 52	33·5	1·12	2	6·2	6·8	·776	S.E.
Hu. 802 ...	0 50	41 5	206·4	0·26	1	7·2	7·8	·047	W.B.
β 302 ...	0 54	69 5	102·4	0·74	1	6·7	8·1	·747	S.E.
Σ 113 ...	1 15	90 58	356·4	1·39	1	6·2	7·2	·006	H.F.
Ho. 310 ...	1 21	61 55	353·2	1·61	2	9·0	9·2	·015	W.B.
Ho. 9 ...	1 24	68 45	97·0	2·78	2	8·8	9·8	·015	W.B.
Σ 138 ...	1 31	82 49	41·3	1·25	1	7·3	7·3	·006	H.F.
			40·5	1·47	2	...		·942	W.B.
β 507 ...	1 31	63 42	152·2	2·15	1	7·8	10·6	·904	W.B.
β 5 ...	1 34	73 50	296 4	1·27	2	7·0	9·0	·942	W.B.
Σ 141 ...	1 35	51 29	299·0	1·75	2	8·0	8·5	·015	W.B.
Σ 149 ...	1 39	50 30	105·0	1·54	2	8·2	9·7	·015	W.B.
Hu. 805 AB	1 47	56 32	166·4	2·70	2	8·8	11·0	·015	W.B.
Σ 178 ...	1 47	79 38	198·2	3·44	1	7·8	7·8	·805	S.E.

Micrometric Observations of Double Stars—continued.

Star's Name.	R.A. 1910	N.P.D. 1910.	Position Angle.	Distance.	No. of Nights.	Mags.		Epoch 1908	Obs.
	h m	° ′	°	″					
Σ 183 AB ...	1 50	61 38	353·6	0·28	1	7·5	8·2	·901	B.
Σ 186 ...	1 51	88 36	30·9	0·58	1	7·2	7·2	·901	B.
Σ 194 ...	1 54	65 36	91·9	1·24	3	8·0	8·3	·922	W.B.
Σ 196 ...	1 55	69 25	51·7	2·42	2	8·5	11·0	·930	W.B.
Ho. 12 ...	1 57	55 46	106·1	3·60	3	8·3	10·6	·038	W.B.
Σ 201 ...	1 58	57 9	119·6	3·64	1	5·3	11·3	·008	W.B.
OΣ 38 ...	1 58	48 6	117·7	0·45	2	5·5	6·5	·113	W.B.
Ho. 312 ...	2 2	64 43	334·1	1·77	1	6·5	12·0	·747	S.E.
Σ 227 ...	2 7	60 6	73·4	3·68	3	5·0	6·4	·076	W.B.
Σ 229 ...	2 9	55 54	353·5	2·31	3	8·6	10·0	·072	W.B.
Tucker ...	2 12	52 20	239·9	3·11	2	8·5	10·5	·015	W.B.
Σ 249 ...	2 16	45 49	192·1	2·22	3	7·0	9·0	·056	W.B.
Ho. 313 ...	2 19	98 13	82·3	1·86	1	8·3	9·0	·006	H.F.
Σ 269 ...	2 24	60 29	338·4	1·81	3	7·5	9·8	·038	W.B.
			343·8	2·10	2	...		·776	S.E.
Küstner 10	2 26	57 29	353·1	3·29	2	9·4	10·0	·015	W.B.
Holden 63 ...	2 30	78 34	286·4	1·07	2	9·0	9·4	·930	W.B.
Ho. 315 ...	2 34	91 58	3·4	1·30	1	8·5	9·0	·006	H.F.
β 1315 AB	2 34	75 53	129·0	1·48	3	8·3	9·3	·940	W.B.
Hu. 1043 ...	2 34	74 57	237·3	2·94	2	9·0	9·5	·930	W.B.
Σ 300 ...	2 39	60 55	305·8	2·98	3	7·9	8·1	·056	W.B.
Σ 305 ...	2 42	71 0	317·6	3·18	1	7·3	8·2	·006	H.F.
Hu. 604 ...	2 43	54 2	192·2	1·64	1	9·0	11·0	·022	W.B.
Σ 310 ...	2 44	56 26	97·6	2·65	3	7·7	10·9	·068	W.B.
Σ 333 ...	2 54	69 1	201·5	1·37	4	5·7	6·0	·268	W.B.
Ho. 318 ...	2 54	73 19	204·2	3·13	2	9·1	9·1	·933	W.B.
Σ 334 ...	2 55	83 43	313·0	1·43	2	7·7	8·2	·933	W.B.
OΣ 49 ...	2 55	72 21	60·4	2·04	2	7·0	10·0	·933	W.B.
OΣ 53 ...	3 12	51 41	221·5	0·43	2	7·2	8·0	·111	W.B.
Σ 381 ...	3 18	69 20	97·2	1·19	2	7·0	8·7	·933	W.B.
Hu. 1058 ...	3 19	50 6	117·4	0·81	2	7·8	8·5	·111	W.B.
Σ 395 ...	3 23	61 15	105·1	2·19	2	8·5	10·0	·061	W.B.
Ait. 983 ...	3 26	60 40	311·0	0·62	1	8·5	9·2	·006	H.F.
Σ 442 ...	3 40	67 33	272·7	2·43	2	9·0	9·5	·130	W.B.
Σ 483 ...	3 58	50 54	196·7	0·59	2	7·4	9·2	·185	W.B.
OΣ 531 ...	4 2	52 10	124·9	1·81	2	6·5	8·2	·130	W.B.
Espin 278 ...	4 3	50 3	171·5	2·23	1	7·7	9·2	·006	H.F.
OΣ 77 ...	4 10	58 31	201·1	0·21	1	7·5	7·5	·175	W.B.

Micrometric Observations of Double Stars—continued.

Star's Name.	R.A. 1910.	N.P.D. 1910.	Position Angle.	Distance.	No. of Nights.	Mags.		Epoch 1908	Obs.
	h m	° ′	°	″					
OΣ 86 ...	4 31	70 25	59·1	0·42	3	7·5	7·5	·073	W.B.
Σ 567 ...	4 31	70 41	319·7	2·20	2	8·5	9·0	·050	W.B.
Hu. 305 ...	4 32	69 8	277·1	2·01	3	9·0	10·2	·073	W.B.
De. 6 ...	4 56	75 37	92·5	0·98	2	9·1	9·3	·050	W.B.
OΣ 95 ...	5 0	70 19	322·9	0·89	1	6·6	7·2	·194	W.B.
Hu. 446 ...	5 2	67 23	180·4	0·83	1	9·2	9·8	·110	L.
Σ 643 ...	5 3	81 42	303·3	2·59	1	8·5	8·5	·110	L.
Σ 645 Aa ...	5 4	62 4	350·9	0·18	1	6·2	6·2	·110	L.
β 1047 BC...			59·4	0·54	1	8·2	8·8	·110	L.
OΣ 98 ...	5 3	81 37	166·8	0·89	1	6·0	6·8	·110	L.
Σ 665 ...	5 10	70 22	257·7	1·69	2	8·3	9·2	·050	W.B.
Σ 670 ...	5 11	71 40	166·8	2·26	2	7·7	8·2	·050	W.B.
OΣ 105 ...	5 17	77 25	297·6	0·59	1	7·8	7·8	·110	L.
Ho. 226 ...	5 21	62 28	57·4	0·65	2	7·5	7·8	·148	W.B.
Σ 719 AB ...	5 24	60 31	324·8	0·84	1	7·0	9·5	·110	L.
β 1267 ...	5 29	59 8	207·4	0·86	1	8·5	8·5	·110	L.
*	5 30	60 15	197·5	0·30	1	10·0	11·0	·110	L.
Σ 749 ...	5 32	63 8	166·6	0·85	2	7·0	7·1	·148	W.B.
β 1240 AB	5 33	59 34	321·8	0·12	1	5·6	6·0	·110	L.
OΣ 112 ...	5 34	52 6	73·7	0·73	1	7·3	8·0	·175	W.B.
OΣ 115 ...	5 39	74 58	116·1	0·85	1	7·1	7·9	·121	W.B.
Σ 835 ...	6 0	71 41	144·6	2·20	2	8·0	9·0	·109	W.B.
OΣ 141 ...	6 25	72 2	136·4	2·19	2	7·5	9·6	·144	W.B.
Σ 932 ...	6 29	75 10	323·4	2·02	2	8·2	8·3	·144	W.B.
OΣ 152 ...	6 34	61 39	37·0	0·75	1	6·0	7·8	·236	H.F.
De. 11 ...	6 36	80 1	45·4	3·83	2	9·1	9·2	·114	W.B.
Σ 950 ...	6 36	80 1	212·1	2·91	2	6·0	8·8	·144	W.B.
AG 119 ...	6 39	66 28	76·1	1·63	1	8·5	9·0	·131	W.B.
Σ 991 ...	6 52	64 55	166·3	3·65	2	8·0	9·0	·109	W.B.
AG 134 AB	6 57	65 24	20·8	1·53	1	9·0	9·2	·131	W.B.
Σ 1037 ...	7 7	62 37	294·5	0·42	1	7·1	7·1	·268	B.
Σ 1081 ...	7 19	68 22	226·3	1·79	2	7·8	8·5	·126	W.B.
Σ 1094 ...	7 22	74 30	96·1	2·23	3	7·7	8·7	·136	W.B.
Σ 1126 ...	7 35	84 34	138·4	1·41	1	7·2	7·5	·266	W.B.
Schj. 8 ...	7 41	76 3	24·2	2·23	2	8·5	9·0	·126	W.B.
Σ 1147 ...	7 45	65 14	165·2	2·31	3	9·0	9·0	·136	W.B.
Ho. 250 ...	7 52	68 47	151·8	0·87	2	7·0	9·0	·255	W.B.
OΣ 186 ...	7 58	63 29	78·3	0·74	1	7·5	8·2	·236	H.F.

Micrometric Observations of Double Stars—continued.

Star's Name.	R.A. 1910. h m	N.P.D. 1910. ° ′	Position Angle. °	Distance. ″	No. of Nights.	Mags.		Epoch 1908	Obs.
Σ 1177 ...	8 0	62 13	350·5	3·46	1	6·5	7·4	·236	H.F.
Σ 1196 AB	8 7	72 4	337·9	1·08	3	5·0	5·7	·250	W.B.
β 1244 ...	8 9	87 44	48·1	0·83	1	7·9	8·1	·236	H.F.
Σ 1216 ...	8 17	91 19	202·5	0·31	1	7·5	8·2	·268	B.
Aitken 551	8 24	92 13	54·1	0·24	1	7·4	7·5	·268	B.
AG 154 ...	8 32	66 26	363·2	1·67	2	9·1	9·3	·207	W.B.
Küstner 32	8 36	70 24	168·5	2·00	2	8·4	10·2	·207	W.B.
Ho. 355 ...	8 38	92 22	178·8	0·39	1	8·3	8·5	·268	B.
Σ 1273 AB	8 42	83 14	183·7	0·25	3	3·8	5·5	·282	W.B.
AC ...			238·4	3·27	4	3·8	7·8	·255	W.B.
AG 157 ...	8 45	66 32	78·1	2·02	3	9·3	9·5	·217	W.B.
Perrotin ...	8 46	81 20	351·0	0·68	1	7·5	8·7	·323	H.F.
Σ 1296 ...	8 54	54 42	73·9	2·41	1	8·5	9·0	·378	L.
Hu. 718 ...	8 55	57 14	194·5	0·39	1	8·7	8·8	·378	L.
Aitken 554	9 0	60 55	211·9	0·98	1	8·5	10·5	·378	L.
Σ 3121 ...	9 13	61 2	39·1	0·33	1	7·5	7·8	·268	B.
			45·8	0·36	1	...		·378	L.
AG 165 ...	9 18	67 27	13·3	1·37	3	9·1	9·3	·203	W.B.
OΣ 201 ...	9 19	61 43	220·9	1·66	3	7·5	9·0	·190	W.B.
β 105 ...	9 19	63 26	205·8	2·73	3	4·5	10·9	·203	W.B.
			206·0	2·85	1	...		·378	L.
Σ 1348 ...	9 20	83 12	321·5	1·92	2	7·5	7·6	·336	W.B.
Lewis 9 ...	9 20	63 36	16·4	2·92	2	9·5	10·0	·197	W.B.
Σ 1355 ...	9 23	83 22	334·2	2·37	2	7·2	7·2	·336	W.B.
Σ 1356 ...	9 24	80 33	113·9	1·11	1	6·2	7·0	·287	S.E.
			119·3	0·99	2	...		·336	W.B.
Σ 1372 ...	9 32	73 19	62·1	0·53	4	8·2	8·3	·241	W.B.
Ho. 369 ...	9 46	53 5	117·3	0·22	1	7·7	7·8	·268	B.
AG 170 ...	9 51	81 28	39·7	1·75	2	9·2	9·2	·256	W.B.
Σ 1396 ...	9 52	78 54	127·9	3·92	2	8·0	10·0	·267	W.B.
Hu. 631 ...	9 59	56 55	276·0	0·74	1	7·0	8·6	·268	B.
			272·8	0·83	1	...		·378	L.
Σ 1406 ...	10 0	58 26	227·9	1·01	1	8·0	8·7	·376	L.
Hu. 874 ...	10 7	76 12	287·6	0·21	1	7·2	8·0	·268	B.
Σ 1413 ...	10 7	73 9	276·4	2·20	2	8·9	8·9	·251	W.B.
OΣ 213 ...	10 8	62 8	100·2	0·97	1	7·8	9·5	·236	H.F.
Lewis 10 ...	10 10	71 40	9·1	1·18	1	8·0	8·5	·236	H.F.
Σ 1417 ...	10 10	70 26	260·7	2·41	1	8·2	8·3	·236	H.F.

Micrometric Observations of Double Stars—continued.

Star's Name.	R.A. 1910. h m	N.P.D. 1910. ° ′	Position Angle. °	Distance. ″	No. of Nights.	Mags.		Epoch 1908	Obs.
OΣ 215 ...	10 11	71 49	203·6	1·12	1	7·0	7·2	·236	H.F.
Σ 1423 ...	10 14	68 59	57·9	1·62	2	8·6	9·3	·242	W.B.
Σ 1424 ...	10 15	69 42	115·6	3·62	1	2·0	3·5	·334	H.F.
Σ 1426 AB	10 16	83 7	280·9	0·91	3	7·5	8·0	·267	W.B.
OΣ 216 ...	10 18	74 11	109·9	1·11	3	7·0	10·5	·264	W.B.
Σ 1429 ...	10 20	64 55	246·6	0·74	2	8·3	8·3	·258	W.B.
Σ 1431 ...	10 21	80 46	69·9	3·51	3	7·5	9·2	·255	W.B.
OΣ 217 ...	10 22	72 19	145·6	0·77	3	7·3	7·8	·250	W.B.
Hu. 879 ...	10 23	52 50	216·8	0·41	1	4·0	6·5	·340	L.
OΣ 220 ...	10 24	79 23	73·1	1·34	2	7·1	9·0	·256	W.B.
Hu. 880 ...	10 26	52 23	126·3	0·74	1	9·0	9·7	·268	B.
Σ 1450 ...	10 30	80 53	156·8	2·33	3	6·0	8·7	·267	W.B.
Σ 1460 ...	10 35	47 22	164·7	3·19	1	8·1	8·1	·446	H.F.
Σ 1465 ...	10 38	44 54	9·2	1·91	1	8·5	8·8	·446	H.F.
Σ 1467 ...	10 39	44 31	292·3	3·98	1	8·0	10·7	·446	H.F.
OΣ 228 ...	10 42	66 57	178·6	0·41	1	7·2	8·1	·378	L.
OΣ 229 ...	10 43	48 23	314·5	0·70	1	6·7	7·1	·446	H.F.
β 915 ...	10 45	65 14	238·3	1·65	1	9·0	9·2	·378	L.
Ho. 374 ...	10 45	66 41	274·0	3·90	1	8·4	12·0	·378	L.
Ho. 376 ...	10 48	66 20	218·7	2·82	1	8·6	10·0	·378	L.
Hu. 567 ...	10 48	67 23	186·9	1·06	1	9·3	10·0	·378	L.
Ho. 47 BC	10 58	53 51	143·2	0·90	1	9·1	9·2	·419	W.B.
Σ 1504 ...	10 59	85 53	287·5	1·27	1	7·5	7·6	·312	H.F.
Ho. 378 ...	11 0	51 6	226·4	0·63	1	8·0	8·3	·419	W.B.
Σ 1517 ...	11 9	69 19	87·6	0·35	3	7·3	7·3	·291	W.B.
			88·0	0·36	1	...		·268	B.
OΣ 232 ...	11 10	51 56	236·4	0·61	1	7·0	7·8	·419	W.B.
Hu. 639 ...	11 10	42 2	268·9	0·28	1	7·5	7·5	·419	W.B.
Σ 1523 ...	11 13	57 54	126·0	2·85	1	4·0	5·0	·287	S.E.
			127·5	2·77	2	...		·451	W.B.
β 791 ...	11 15	82 38	194·0	2·23	1	8·3	10·3	·312	H.F.
Σ 1536 ...	11 19	78 58	49·1	2·18	3	3·9	7·1	·337	W.B.
Σ 1537 ...	11 20	68 53	353·5	2·41	3	7·6	9·6	·317	W.B.
β 340 ...	11 25	86 18	10·2	3·81	1	8·4	9·6	·312	H.F.
Lewis 11 ...	11 25	59 4	2·5	0·88	2	7·0	11·0	·359	L.
OΣ 234 ...	11 26	48 13	153·3	0·39	1	7·0	7·4	·419	W.B.
Hu. 727 ...	11 28	40 3	18·2	1·06	1	8·8	9·2	·446	H.F.
AG 175 ...	11 30	88 0	185·6	2·48	1	8·6	8·9	·312	H.F.

Micrometric Observations of Double Stars—continued.

Star's Name.	R.A. 1910. h m	N.P.D. 1910. ° ′	Position Angle. °	Distance. ″	No. of Nights.	Mags.		Epoch 1908	Obs
Σ 1554 ...	11 31	76 39	257·7	0·87	3	8·8	8·8	·322	W.B.
Σ 1555 AB	11 32	61 43	356·0	0·21	4	6·4	6·8	·343	W.B.
Küstner 39	11 32	42 2	202·4	2·04	1	9·5	9·8	·446	H.F.
OΣ 237 ...	11 34	48 21	266·4	1·45	2	7·4	9·0	·451	W.B.
β 792 ...	11 37	86 38	196·4	2·20	1	8·3	11·0	·312	H.F.
Küstner 40	11 44	55 48	182·3	2·77	2	9·4	10·0	·406	W.B.
β 603 ...	11 44	75 13	303·9	0·90	2	6·4	10·2	·293	W.B.
H. 842 ...	11 47	44 41	90·8	2·97	1	8·5	8·9	·446	H.F.
Σ 1581 ...	11 51	43 57	173·9	2·32	1	8·3	9·5	·446	H.F.
OΣ 241 ...	11 52	54 3	130·7	1·63	2	6·5	8·4	·406	W.B.
Hu. 733 ...	11 53	41 27	162·3	1·61	1	8·7	10·3	·446	H.F.
Ait. 681 ...	11 59	64 24	123·9	0·57	2	8·9	9·3	·293	W.B.
Σ 1593 ...	11 59	91 57	192·3	1·27	1	8·3	8·3	·312	H.F.
Σ 1601 ...	12 2	50 40	308·9	2·34	2	8·5	9·7	·406	W.B.
Σ 1606 ...	12 6	49 33	325·8	1·17	2	6·3	7·0	·406	W.B.
Σ 1613 ...	12 8	53 44	9·0	1·40	2	8·5	8·8	·406	W.B.
Hu. 569 ...	12 9	67 47	154·0	1·03	1	9·0	11·5	·312	H.F.
AG 176 ...	12 12	59 26	178·3	2·71	2	9·0	9·2	·406	W.B.
β 796 ...	12 13	82 54	271·5	0·57	1	8·0	8·5	·312	H.F.
Σ 1639 ...	12 20	63 55	346·0	0·39	4	6·7	7·9	·341	W.B.
			354·0	0·45	2	...		·335	B.
Σ 1643 ...	12 23	62 28	35·3	2·12	2	8·7	9·2	·273	W.B.
β 1324 ...	12 25	59 59	221·8	2·69	2	9·3	9·9	·406	W.B.
Σ 1647 ...	12 26	79 47	221·6	1·58	2	7·5	7·8	·273	W.B.
			223·6	1·35	1	...		·312	H.F.
Σ 1661 ...	12 31	78 6	239·4	2·30	1	8·5	8·5	·364	H.F.
Σ 1663 ...	12 33	68 18	107·7	0·62	2	7·8	8·7	·406	W.B.
β 607 ...	12 37	90 58	316·9	0·92	1	9·0	10·0	·364	H.F.
β 924 ...	12 37	82 42	29·0	3·87	1	5·8	11·5	·364	H.F.
Hu. 892 ...	12 38	74 59	162·7	1·00	2	9·3	9·3	·307	B.
β 928 ...	12 39	95 57	311·1	1·77	1	7·9	8·9	·312	H.F.
Σ 1674 ...	12 39	81 57	171·9	2·11	3	8·5	9·2	·350	W.B.
			171·3	2·92	1	...		·353	J.S.
Hu. 893 ...	12 43	77 13	29·4	1·47	2	9·1	9·1	·307	B.
Holden 117	12 45	81 52	195·0	2·39	2	9·1	9·5	·358	W.B.
Hu. 640 ...	12 46	68 59	119·8	0·40	2	9·5	9·5	·307	B.
Hu. 894 ...	12 49	76 20	140·2	0·99	2	9·1	9·1	·307	B.
Σ 1687 ...	12 49	68 16	92·6	1·12	2	5·2	8·0	·451	W.B.

Micrometric Observations of Double Stars—continued.

Star's Name.	R.A. 1910. h m	N.P.D. 1910. ° ′	Position Angle. °	Distance. ″	No. of Nights.	Mags.	Epoch 1908	Obs.
OΣ 256 ...	12 52	90 28	78·3	0·77	1	7·2 7·6	·312	H.F.
			74·4	0·68	2	...	·374	B.
Holden 14	12 56	86 39	261·3	2·35	1	8·3 10·5	·312	H.F.
Σ 1711 ...	12 58	76 3	350·3	0·88	3	8·5 9·0	·324	W.B.
Σ 1709 ...	12 58	66 1	248·5	2·77	2	7·4 9·7	·358	W.B.
β 929 ...	12 59	93 11	216·1	0·88	1	6·0 6·3	·312	H.F.
Σ 1728 ...	13 6	72 0	191·4	0·47	4	6·0 6·0	·341	W.B.
OΣ 261 ...	13 8	57 26	343·6	2·14	1	6·9 7·4	·287	S.E
			342·7	1·67	2	...	·406	W.B.
			344·8	1·78	2	...	·441	B.
β 800 ...	13 12	72 30	110·3	3·02	2	7·3 10·4	·359	W.B.
Ho. 260 ...	13 19	60 18	320·0	0·72	3	8·2 8·2	·437	W.B.
OΣ 269 ...	13 29	54 38	220·4	0·30	1	6·5 7·0	·402	B.
Σ 1779 ...	13 40	65 53	147·6	4·00	2	8·5 9·8	·370	W.B.
			146·1	4·50	1	...	·353	J.S.
β 801 ...	13 42	78 43	325·6	2·51	1	8·1 10·9	·364	H.F.
Σ 1785 ...	13 45	62 34	318·2	1·38	1	7·2 7·5	·364	H.F.
OΣ 272 ...	13 50	59 39	11·1	1·86	3	7·0 9·9	·497	W.B.
OΣ 273 ...	13 52	84 16	108·8	1·05	2	7·5 8·0	·377	W.B.
Σ 1792 ...	13 53	77 7	293·4	1·98	3	8·9 10·1	·418	W.B.
AG 192 ...	13 59	86 52	186·5	1·18	1	9·0 10·0	·364	H.F.
OΣ 279 ...	14 9	77 35	253·1	2·10	2	6·8 9·0	·377	W.B.
Σ 1828 ...	14 13	65 23	158·2	2·17	2	9·8 10·2	·488	W.B.
OΣ 281 ...	14 16	81 0	158·1	1·49	2	7·3 10·8	·370	W.B.
			166·6	2·12	1	...	·353	J.S.
Σ 1834 ...	14 17	41 5	358·9	0·13	1	7·1 7·2	·575	B.
Ait. 570 ...	14 28	62 55	162·4	0·22	2	6·3 6·5	·499	W.B.
Howe 34 ...	14 36	77 31	193·3	2·69	3	8·7 9·2	·369	W.B.
			191·8	3·43	1	...	·353	J.S.
Σ 1863 ...	14 37	75 53	146·3	0·51	3	3·5 3·9	·409	B.
			139·8	0·35	3	...	·519	W.B.
Hu. 575 ...	14 38	70 7	135·9	0·70	2	9·0 9·5	·499	W.B.
Σ 1875 ...	14 40	51 53	128·2	3·08	4	8·7 9·2	·493	W.B.
Σ 1877 ...	14 41	62 33	323·1	2·25	1	3·0 6·3	·556	H.F.
Ho. 263 ...	14 44	65 32	174·4	1·01	2	7·0 10·0	·499	W.B.
Σ 1888 ...	14 47	70 32	154·6	2·40	3	4·7 6·6	·391	W.B.
			152·7	2·23	1	...	·556	H.F.
OΣ 288 ...	14 49	73 56	189·5	1·75	2	6·4 7·1	·488	W.B.

Micrometric Observations of Double Stars—continued.

Star's Name.	R.A. 1910. h m	N.P.D. 1910. ° ′	Position Angle. °	Distance. ″	No. of Nights.	Mags.		Epoch 1908	Obs.
β 348 ...	14 57	89 47	110·7	0·60	1	6·0	7·5	·556	H.F.
Σ 1907 ...	15 1	78 1	360·7	1·22	2	8·5	8·7	·370	W.B.
			365·8	1·14	1	...		·353	J.S.
Σ 1911 ...	15 3	77 41	292·2	2·08	2	9·0	9·8	·408	W.B.
Σ 1917 ...	15 8	74 17	236·4	2·64	2	9·0	9·3	·408	W.B.
Σ 3091 ...	15 11	94 34	27·5	0·33	1	7·7	7·7	·345	B.
β 32 ...	15 16	88 58	9·6	1·60	1	5·8	10·0	·556	H.F.
Ho. 62 ...	15 17	54 42	275·8	1·43	1	8·3	8·4	·608	L.
Σ 1937 ...	15 19	59 24	29·0	1·13	2	5·5	6·0	·486	W.B.
Σ 1941 ...	15 22	63 3	223·6	1·57	2	8·7	8·7	·403	W.B.
Σ 1944 ...	15 23	83 36	324·3	0·92	1	7·5	8·1	·556	H.F.
Küstner 50	15 24	43 31	335·4	3·30	1	9·5	9·9	·608	L.
Σ 1950 ...	15 26	64 11	93·3	3·33	2	6·7	8·2	·488	W.B.
Σ 1954 ...	15 31	79 10	182·8	3·29	1	3·2	4·1	·485	H.F.
Σ 1957 ...	15 32	76 47	152·0	1·05	2	7·9	9·6	·540	W.B.
OΣ 298 ...	15 33	49 54	191·0	1·13	3	7·0	7·3	·569	B.
			187·2	1·41	1	...		·608	L.
Σ 1964 BC	15 35	53 28	15·2	1·88	1	7·3	8·8	·608	L.
AG 167 ...	15 36	68 26	125·4	3·02	2	9·0	9·1	·540	W.B.
Hu. 580 ...	15 38	70 3	88·9	0·11	3	5·0	5·0	·626	B.
β 619 ...	15 39	76 3	5·9	0·57	2	6·9	7·7	·521	H.F.
Σ 1967 ...	16 39	63 25	116·1	0·56	3	4·0	7·0	·476	W.B.
			116·6	0·60	1	...		·512	L.
Hu. 747 ...	15 49	69 43	116·6	2·55	2	9·0	13·0	·531	L.
			118·4	2·09	1	...		·515	W.B.
Ho. 399 ...	15 52	60 12	118·9	3·19	2	7·5	10·0	·531	L.
			117·5	2·73	1	...		·515	W.B.
Σ 1988 ...	15 53	77 15	260·9	2·52	2	7·5	8·2	·434	W.B.
OΣ 303 ...	15 57	76 28	143·4	0·89	2	7·4	7·9	·463	W.B.
Σ 1998 ...	15 59	101 8	119·1	0·27	1	4·9	5·2	·402	B.
Σ 2000 ...	15 59	75 45	227·3	2·73	1	8·2	9·0	·512	L.
			228·1	2·43	2	...		·537	W.B.
β 811 ...	16 2	67 35	220·9	3·43	2	7·9	10·4	·531	L.
			220·2	3·69	2	...		·558	W.B.
β 812 ...	16 3	72 52	124·5	0·68	2	8·2	8·3	·531	L.
			122·5	0·69	4	...		·553	W.B.
Σ 2021 ...	16 9	76 14	333·8	3·77	1	6·7	6·9	·485	H.F.

Micrometric Observations of Double Stars—continued.

Star's Name.	R.A. 1910. h m	N.P.D. 1910. ° ′	Position Angle. °	Distance. ″	No. of Nights.	Mags.		Epoch 1908	Obs.
Σ 2022 ...	16 9	63 6	141·1	2·52	2	6·2	9·8	·531	L.
			135·6	2·53	2	...		·558	W.B.
Σ 2023 ...	16 10	84 15	223·2	1·98	1	8·3	9·0	·556	H.F.
Σ 2032 ...	16 11	55 55	216·6	5·16	1	5·0	6·1	·608	L.
Hu. 480 ...	16 12	70 3	244·3	1·13	1	9·0	10·2	·556	H.F.
Ait. 348 ...	16 13	60 11	122·3	1·15	2	8·2	10·5	·531	L.
OΣ 309 ...	16 16	48 7	72·9	0·41	4	7·5	7·7	·714	B.
Küstner 43	16 20	51 31	37·2	2·83	1	9·7	10·1	·608	L.
OΣ 310 AB	16 22	51 53	333·6	3·68	1	7·6	10·2	·608	L.
Σ 2049 ...	16 24	63 49	213·6	1·18	1	6·5	7·5	·550	L.
β 813 ...	16 24	63 16	166·7	0·97	1	8·4	8·4	·550	L.
Σ 2052 ...	16 25	71 24	85·4	1·05	1	7·5	7·5	·550	L.
Σ 2061 ...	16 30	58 54	25·1	2·61	2	7·1	9·9	·630	W.B.
OΣ 314 ...	16 35	69 22	234·1	3·85	1	7·2	10·1	·550	L.
Hu. 486 ...	16 36	67 6	143·8	1·04	1	9·0	10·0	·550	L.
Ait. 349 ...	16 38	59 41	106·3	0·67	2	9·2	10·0	·714	L.
Σ 2084 ...	16 38	58 15	164·6	1·07	3	3·0	6·5	·601	B.
			156·4	1·15	8	...		·681	W.B.
			161·7	1·25	3	...		·710	L.
Hu. 487 ...	16 38	67 59	25·1	0·53	1	9·0	9·0	·633	B.
Σ 2091 ...	16 39	48 38	305·0	1·10	2	7·5	8·0	·611	W.B.
Σ 2094 AB	16 40	66 19	77·8	1·38	3	7·3	7·6	·586	W.B.
De. 15 ...	16 41	46 21	293·9	0·46	3	8·1	8·6	·620	W.B.
Küstner 55	16 44	75 1	45·8	2·60	1	9·5	10·1	·556	H.F.
Weisse 31 BC	16 44	64 12	246·1	2·25	1	8·7	8·7	·556	H.F.
Σ 2106 ...	16 47	80 26	276·3	0·27	1	6·7	8·4	·633	B.
OΣ 315 ...	16 47	88 38	157·7	0·77	1	6·2	8·1	·556	H.F.
Σ 2107 ...	16 48	61 11	7·5	0·48	5	6·5	8·0	·671	W.B.
			358·9	0·43	1	...		·685	L.
β 821 ...	16 48	58 0	312·1	1·36	2	8·4	8·9	·611	W.B.
*	16 50	60 45	162·7	0·69	1	...		·685	L.
OΣ 318 ...	16 53	75 43	239·1	2·61	1	6·7	9·3	·556	H.F.
OΣ 319 ...	16 54	74 43	57·4	0·68	1	7·5	8·5	·556	H.F.
Σ 2118 ...	16 56	24 50	92·9	0·31	2	6·4	6·9	·777	B.
OΣ 322 ...	16 57	52 57	212·1	1·68	1	7·0	9·8	·726	L.
β 822 ...	17 0	70 12	224·1	1·41	3	6·9	11·3	·497	W.B.
Ho. 555 ...	17 1	56 39	182·7	1·07	3	9·3	9·3	·620	W.B.
Ait. 228 ...	17 3	63 22	190·1	0·58	1	9·0	9·2	·685	L.

Micrometric Observations of Double Stars—continued.

Star's Name.	R.A. 1910. h m	N.P.D. 1910. ° ′	Position Angle. °	Distance. ″	No. of Nights.	Mags.		Epoch 1908	Obs.
Hu. 1176 ...	17 5	53 56	108·4	0·15	5	6·0	6·0	·702	B.
			176·1	0·21	2	...		·752	W.B.
Σ 2145 AB	17 13	63 19	31·5	0·16	1	8·3	9·3	·685	L.
			39·6	0·52	1	...		·783	W.B.
β 629 ...	17 14	57 49	335·0	1·04	2	8·3	9·0	·611	W.B.
β 628 ...	17 15	57 15	346·5	0·53	3	9·0	9·5	·701	W.B.
Σ 2154 ...	17 16	45 47	248·6	1·91	2	8·5	9·3	·755	W.B.
β 630 ...	17 16	57 34	217·6	1·97	1	8·7	10·7	·783	W.B.
Ait. 232 ...	17 18	64 12	106·5	0·63	1	8·7	9·4	·685	L.
β 46 ...	17 20	76 31	202·2	1·92	2	7·7	10·9	·579	W.B.
Hu. 1179 ...	17 21	51 20	277·4	0·22	5	7·0	7·1	·672	B.
Σ 2170 ...	17 24	79 27	67·6	3·70	3	8·5	9·0	·593	W.B.
Σ 2177 ...	17 25	43 31	134·9	3·37	2	8·5	10·0	·755	W.B.
Ho. 417 ...	17 26	51 29	154·3	0·40	2	8·0	8·0	·604	B.
Ho. 420 ...	17 35	52 58	106·8	1·62	2	9·5	10·0	·604	B.
Σ 2203 ...	17 38	48 18	318·8	0·73	3	7·5	7·8	·701	W.B.
Ho. 560 ...	17 40	56 1	95·1	0·53	3	8·0	8·0	·701	W.B.
Σ 2206 ...	17 41	70 58	247·0	1·30	1	8·1	9·7	·685	L.
Σ 2205 ...	17 42	72 15	313·2	2·07	1	7·0	7·2	·685	L.
Σ 2215 ...	17 43	72 17	293·9	0·70	1	5·9	7·9	·685	L.
Lewis 16 ...	17 47	74 40	346·6	1·18	1	10·0	10·5	·685	L.
			339·2	0·75	2	...		·644	B.
*with Lew. 16	17 47	74 40	282·4	1·40	1	...		·712	B.
Σ 2238 ...	17 47	52 14	291·9	2·36	2	9·2	9·7	·611	W.B.
OΣ 338 ...	17 48	74 40	16·2	0·88	2	6·6	6·9	·604	B.
			14·2	0·93	1			·685	L.
Lewis 17 ...	17 49	74 29	292·4	2·30	1	9·0	9·5	·712	B.
Ait. 235 ...	17 50	65 0	82·8	0·36	3	7·9	8·1	·653	B.
β 130 ...	17 50	49 58	122·9	1·64	3	6·0	9·7	·706	W.B.
Σ 2243 ...	17 50	53 53	44·8	1·59	2	8·3	8·8	·684	W.B.
β 417 ...	17 53	50 33	277·8	1·53	2	8·1	10·0	·755	W.B.
Hu. 235 ...	17 55	44 8	266·7	1·47	2	6·7	9·3	·755	W.B.
Σ 2267 ...	17 59	49 49	242·2	1·08	2	8·0	8·0	·755	W.B.
Σ 2272 ...	18 1	87 27	158·5	2·89	21	4·5	6·0	·629	W.B.
OΣ 534 ...	18 1	68 34	273·2	2·23	2	7·5	9·5	·508	W.B.
AG 216 ...	18 3	86 44	91·7	2·48	2	9·0	9·1	·508	W.B.
Σ 2285 ...	18 5	76 32	330·3	3·47	2	8·2	10·0	·569	W.B.
Σ 2289 ...	18 6	73 33	227·9	1·18	2	6·0	7·1	·569	W.B.

Micrometric Observations of Double Stars—continued.

Star's Name.	R.A. 1910. h m	N.P.D. 1910. ° ′	Position Angle. °	Distance. ″	No. of Nights.	Mags.		Epoch 1908	Obs.
Hu. 316 ...	18 6	71 45	149·3	1·82	3	9·0	10·1	·572	W.B.
Hu. 317 ...	18 7	72 48	20·0	1·80	2	8·5	8·8	·569	W.B.
Σ 2292 ...	18 9	62 23	268·8	1·24	4	8·0	8·1	·598	W.B.
Perrine ...	18 16	75 59	4·0	3·41	3	8·8	10·2	·586	W.B.
AG 221 ...	18 16	68 42	10·7	1·45	3	9·0	9·4	·590	W.B.
AG 222 ...	18 18	75 49	144·2	1·76	2	8·6	8·8	·569	W.B.
β 641 ...	18 18	68 32	349·7	0·81	1	7·1	9·0	·780	L.
Ho. 430 ...	18 18	69 32	195·4	2·40	3	8·5	9·0	·572	W.B.
			197·8	2·44	1	...		·780	L.
Hu. 583 ...	18 26	76 16	306·6	0·79	3	8 6	9·1	·648	W.B.
Hu. 245 ...	18 29	78 17	55·9	2·13	3	8·2	9·2	·580	W.B.
OΣ 357 ...	18 32	78 21	235·8	0·37	3	7·5	7·6	·693	W.B.
OΣ 359 ...	18 32	66 28	338·7	0·43	1	6·6	6·9	·715	H.F.
Ait. 249 ...	18 32	65 13	278·5	1·03	2	9·3	9·5	·596	W.B.
OΣ 358 ...	18 32	72 6	190·4	1·71	1	6·8	7·2	·734	H.F.
OΣ 360 ...	18 34	85 14	289·4	1·17	1	6·5	10·0	·715	H.F.
Σ 2356 ...	18 35	61 23	55·4	1·02	3	8·0	9·0	·604	W.B.
β 1328 ...	18 36	87 3	283·7	1·94	1	8·6	9·4	·715	H.F.
Σ 2369 ...	18 39	87 28	95·2	0·76	1	7·5	8·0	·715	H.F.
Σ 2392 ...	18 42	50 52	314·0	2·93	2	8·2	10·2	·755	W.B.
Σ 2402 ...	18 46	79 26	205·2	1·06	1	8·0	8·4	·715	H.F.
β 265 ...	18 46	78 35	230·8	1·38	2	7·1	9·1	·596	W.B.
Σ 2408 ...	18 48	79 20	89·5	1·50	1	7·5	8·7	·715	H.F.
β 421 ...	18 49	46 43	293·2	1·09	2	9·1	9·3	·755	W.B.
Σ 2415 ...	18 51	69 30	292·5	2·00	2	6·6	8·5	·636	W.B.
β 137 AB ...	18 51	52 44	135·8	1·41	1	8·2	8·7	·726	L.
			135·1	1·40	2	...		·755	W.B.
Ho. 90 ...	18 51	52 48	223·5	3·93	1	8·2	12·0	·726	L.
			223·2	3·92	3	...		·764	W.B.
Σ 2422 ...	18 53	64 2	95·5	0·80	4	7·6	7·7	·695	W.B.
Σ 2430 ...	18 56	60 32	360·3	1·91	2	8·5	8·5	·755	W.B.
Σ 2437 ...	18 58	70 58	57·1	0·77	2	7·8	8·0	·712	W.B.
Bird 4 ...	19 1	57 22	315·0	2·39	1	8·4	8·6	·734	H.F.
β 466 ...	19 1	79 18	164·1	1·89	2	9·2	10·0	·712	W.B.
Dawes 9 ...	19 2	46 15	177·5	1·93	3	7·4	11·0	·754	W.B.
Ho. 95 ...	19 2	62 51	213·8	0·43	4	8·0	8·2	·774	W.B.
Σ 2454 ...	19 3	59 42	256·7	1·27	1	8·0	9·2	·726	L.
			248·2	0·90	3	...		·756	W.B.

Micrometric Observations of Double Stars—continued.

Star's Name.	R.A. 1910. h m	N.P.D. 1910. ° ′	Position Angle. °	Distance. ″	No. of Nights.	Mags.		Epoch 1908	Obs.
Σ 2465 ...	19 4	59 28	246·9	1·51	1	8·3	10·2	·685	L.
Σ 2466 ...	19 4	60 20	104·8	2·36	2	8·0	8·5	·596	W.B.
			107·9	2·49	1	...		·685	L.
Σ 2469 ...	19 5	51 13	123·7	1·49	4	7·7	8·8	·715	W.B.
Ho. 98 ...	19 5	63 3	135·8	0·29	3	8·0	8·0	·782	W.B.
Ho. 444 ...	19 5	63 12	78·0	1·38	5	8·4	10·0	·625	W.B.
Ho. 99 ...	19 5	59 38	131·5	0·54	2	9·0	9·0	·752	W.B.
Ho. 443 ...	19 6	70 44	116·5	3·00	2	9·5	9·5	·633	W.B.
Ho. 442 ...	19 6	70 55	94·0	3·73	2	9·3	10·3	·652	W.B.
Σ 2482 ...	19 9	71 1	343·3	2·01	3	8·5	9·2	·613	W.B.
β 139 ...	19 9	73 18	137·3	0·62	1	7·0	8·0	·734	H.F.
Ait. 368 ...	19 12	74 0	154·8	0·52	2	7·3	8·5	·754	W.B.
OΣ 371 ...	19 12	62 42	153·5	0·91	2	6·8	6·9	·752	W.B.
Ho. 447 ...	19 13	62 14	175·3	2·12	3	9·8	9·9	·771	W.B.
Σ 2491 ...	19 13	61 53	218·6	1·24	2	7·9	9·2	·752	W.B.
Hu. 336 ...	19 13	71 17	196·8	1·41	3	8·9	9·2	·689	W.B.
Σ 2492 ...	19 14	89 5	11·6	3·32	1	5·5	9·5	·660	W.B.
β 141 AB ...	19 18	67 40	89·8	1·03	1	7·5	8·5	·685	L.
OΣ 373 ...	19 21	43 45	232·3	1·65	3	7·3	10·2	·766	W.B.
Σ 3111 ...	19 21	68 21	119·9	2·37	2	9·0	9·4	·776	W.B.
Espin 80 ...	19 21	57 2	188·7	3·79	2	8·6	9·0	·749	W.B.
Ait. 159 AB	19 23	69 30	333·5	0·90	2	8·2	11·7	·826	W.B.
Σ 2525 ...	19 23	62 52	310·8	0·62	2	7·5	7·7	·771	L.
			307·6	0·74	2	...		·836	W.B.
Ho. 450 ...	19 23	51 22	272·0	1·00	2	8·0	8·7	·755	W.B.
β 143 ...	19 27	40 41	192·3	2·09	2	8·0	9·1	·777	W.B.
Ait. 269 ...	19 27	62 57	169·3	0·59	2	8·8	9·5	·836	W.B.
β 53 ...	19 31	78 45	244·8	1·53	2	9·2	10·0	·652	W.B.
AG 234 ...	19 32	53 55	327·3	2·62	2	9·3	9·4	·787	W.B.
OΣ 377 ...	19 33	54 33	38·1	0·86	2	8·4	8·5	·752	W.B.
Ho. 110 ...	19 35	71 31	78·2	2·54	3	9·5	9·5	·708	W.B.
Σ 2556 ...	19 36	67 57	139·6	0·47	2	7·3	7·3	·836	W.B.
β 145 AB ...	19 38	59 30	266·7	0·83	3	6·8	9·5	·771	W.B.
OΣ 382 ...	19 38	62 50	352·0	0·37	2	7·1	7·6	·752	W.B.
OΣ 380 ...	19 38	78 23	73·2	0·44	2	6·0	7·2	·637	W.B.
OΣ 383 ...	19 40	49 30	21·5	1·13	2	7·0	8·5	·777	W.B.
β 657 ...	19 40	67 35	144·6	0·92	1	9·2	10·0	·715	H.F.
OΣ 384 ...	19 41	51 54	192·4	1·10	3	7·0	7·3	·844	W.B.

Micrometric Observations of Double Stars—continued.

Star's Name.	R.A. 1910.	N.P.D. 1910.	Position Angle.	Distance.	No. of Nights.	Mags.		Epoch 1908	Obs.
	h m	° ′	°	″					
Σ 2569 ...	19 41	73 24	0·4	1·98	1	8·0	8·5	·715	H.F.
AG 237 ...	19 42	59 25	145·3	2·08	1	8·6	9·2	·715	H.F.
Σ 2576 ...	19 42	56 36	289·1	2·45	2	7·8	7·8	·790	W.B.
Dawes 13 ...	19 42	45 18	270·1	2·09	1	7·5	11·3	·830	W.B.
Hu. 758 ...	19 44	56 53	144·5	0·98	1	9·0	9·0	·715	H.F.
			146·6	0·80	1	...		·726	L.
Σ 2583 ...	19 44	78 25	115·7	1·57	2	6·1	6·7	·741	W.B.
			116·9	1·57	1	...		·748	S.E.
AGC 11 ...	19 45	71 5	113·8	0·18	4	6·0	6·3	·734	B.
OΣ 386 ...	19 45	53 4	76·4	1·01	1	7·7	8·0	·715	H.F.
OΣ 387 ...	19 45	54 56	325·6	0·59	3	7·2	8·2	·844	W.B.
* ...	19 45	56 28	198·0	3·62	1	9·2	9·7	·726	L.
β 361 ...	19 46	67 34	350·1	3·40	2	9·2	9·9	·686	H.F.
β 978 ...	19 47	66 43	231·6	0·99	1	8·3	8·4	·715	H.F.
OΣ 388 AB	19 49	64 22	137·7	3·40	2	7·6	7·6	·686	H.F.
AG 242 ...	19 50	53 10	180·2	1·82	3	9·2	9·7	·844	W.B.
OΣ 395 ...	19 58	65 19	107·6	0·63	1	5·8	6·2	·715	H.F.
			106·6	0·75	1	...		·748	S.E.
Σ 2616 ...	19 59	75 40	268·0	2·92	1	6·8	9·7	·657	H.F.
			266·1	3·77	1	...		·748	S.E.
Ait. 1194 ...	19 59	77 56	302·4	0·70	2	8·9	9·0	·692	B.
Ait. 1197 ...	20 2	60 31	339·3	0·30	1	9·0	9·5	·761	L.
Ait. 1201 ...	20 8	61 10	173·3	0·40	1	9·0	9·1	·761	L.
Doo. 14 ...	20 8	64 23	263·5	1·95	1	9·2	10·0	·821	W B.
Doo. 15 ...	20 9	64 38	173·4	2·39	1	9·0	10·7	·895	L.
* ...	20 10	66 3	297·9	1·60	1	8·5	9·5	·895	L.
Σ 2653 ...	20 10	66 3	262·6	2·45	2	7·0	10·1	·824	W.B.
			269·8	2·61	2	...		·876	L.
β 983 ...	20 11	64 41	156·0	0·85	2	6·1	10·2	·876	L.
β 984 ...	20 14	63 55	207·4	0·80	2	7·9	8·2	·834	W.B.
			213·2	0·89	2	...		·876	L.
Ait. 1205 ...	20 14	61 6	346·4	0·32	1	8·9	9·7	·761	L.
OΣ 405 ...	20 15	57 1	147·6	0·70	2	7·7	8·7	·826	W.B.
Ait. 1207 ...	20 15	60 23	357·6	0·54	1	9·5	10·2	·761	L.
* ...	20 16	61 2	96·0	0·50	1	9·4	9·6	·761	L.
β 431 ...	20 17	54 1	32·6	0·63	2	8·5	8·8	·826	W.B.
Σ 2672 ...	20 18	66 31	299·6	0·79	1	8·7	8·8	·857	L.
β 432 ...	20 21	54 31	189·9	1·35	2	8·6	9·9	·835	W.B.

Micrometric Observations of Double Stars—continued.

Star's Name.	R.A. 1910. h m	N.P.D. 1910. ° ′	Position Angle.	Distance.	No. of Nights.	Mags.		Epoch 1908	Obs.
De. 22 ...	20 22	50 12	146·0	2″·89	2	7·9	9·0	·855	W.B.
Σ 2690 ...	20 27	79 3	218·5	0·38	3	7·5	7·5	·755	B.
Σ 2695 ...	20 28	64 30	79·6	1·01	2	6·8	8·0	·834	W.B.
β 151 ...	20 33	75 43	138·6	0·21	4	4·5	6·0	·734	B.
Ho. 137 ...	20 37	60 31	296·5	0·76	1	6·2	11·2	·857	L.
AG 264 ...	20 42	65 38	0·0	1·98	1	9·0	9·1	·895	L.
OΣ 418 ...	20 51	57 38	291·1	1·22	2	7·3	7·4	·853	W.B.
Hu. 363 ...	20 55	71 58	91·7	0·53	2	9·3	9·3	·652	W.B.
Ho. 282 ...	21 0	44 30	353·1	0·26	2	7·1	8·0	·777	B.
Ait. 178 ...	21 2	69 4	69·4	0·85	1	8·1	9·3	·884	W.B.
Ho. 152 ...	21 9	62 2	324·5	0·59	1	8·2	8·6	·884	W.B.
OΣ 535 ...	21 10	80 22	33·2	0·24	8	4·6	5·1	·772	W.B.
			37·1	0·25	5	...		·767	B.
			33·6	0·24	2	...		·828	L.
Hu. 767 ...	21 10	74 24	179·7	0·22	1	7·0	7·0	·884	W.B.
Ho. 286 ...	21 16	52 8	328·6	0·15	1	6·5	6·5	·786	B.
Hu. 371 ...	21 31	65 57	151·3	0·24	3	7·0	7·5	·741	B.
OΣ 448 ...	21 37	61 4	226·8	0·81	2	7·7	8·7	·882	W.B.
Hu. 280 ...	21 38	84 30	137·9	0·30	3	7·7	8·1	·717	B.
Ho. 165 ...	21 38	71 25	76·3	0·60	1	8·0	8·4	·761	L.
			69·7	0·46	1	...		·884	W.B.
Ho. 166 ...	21 40	62 34	70·2	0·39	2	7·5	7·5	·652	W.B.
β 989 AB ...	21 41	64 46	70±	...	1	4·3	5·0	·649	W.B.
			54·7	0·25	1	...		·654	W.B.
			76·0	0·11	3	...		·755	B.
			61·6	[0·10]	1	...		·783	W.B.
			55·8	[0·15]	1	...		·841	W.B.
			71·2	0·08	1	...		·895	L.
Ho. 171 ...	21 48	62 38	172·5	0·87	1	8·1	8·2	·884	W.B.
Hu. 978 ...	22 8	76 32	222·7	0·47	2	8·5	9·0	·652	W.B.
Ho. 179 ...	22 9	60 14	267·8	0·70	1	8·2	8·7	·895	L.
Σ 2881 ...	22 10	60 52	97·0	1·81	1	7·7	8·2	·895	L.
Ho. 292 ...	22 19	84 48	67·4	3·83	2	8·0	11·5	·652	W.B.
Σ 2900 ...	22 19	69 36	174·5	1·59	1	6·0	9·2	·780	L.
Ho. 183 ...	22 21	67 53	221·7	2·24	1	8·2	10·8	·780	L.
Ho. 296 ...	22 36	75 56	58·7	0·43	3	5·5	5·5	·818	B.
Ho. 482 ...	22 47	64 5	44·1	0·20	1	7·5	7·5	·767	B.
Ho. 194 ...	23 2	48 41	59·0	0·32	1	7·0	9·3	·047	W.B.

Micrometric Observations of Double Stars—continued.

Star's Name.	R.A. 1910.	N.P.D. 1910.	Position Angle.	Distance.	No. of Nights.	Mags.	Epoch 1908	Obs.
	h m	° ′	°	″				
Ho. 196 ...	23 4	60 1	290·1	1·78	2	8·0 9·5	·664	W.B.
Σ 2979 ...	23 4	50 43	221·2	2·93	2	8·0 10·0	·042	W.B.
Σ 2989 ...	23 9	70 30	139·8	1·58	2	8·5 9·9	·850	W.B.
			138·8	1·75	1	...	·857	L.
Σ 2990 ...	23 9	68 25	62·0	1·96	2	8·0 8·1	·824	W.B.
			64·4	2·12	1	...	·857	L.
Ho. 299 ...	23 10	66 15	80·0	1·07	1	8·0 10·2	·857	L.
Ho. 198 ...	23 13	73 38	33·6	2·36	1	8·0 9·0	·857	L.
OΣ 494 ...	23 16	68 33	83·6	3·40	2	7·4 8·1	·838	L.
			81·5	3·31	2	...	·824	W.B.
β 718 ...	23 18	58 41	94·1	0·39	2	5·0 8·7	·354	W.B.
OΣ 495 ...	23 20	32 58	300·8	0·43	1	7 3 7·5	·027	H.F.
Espin 108 ...	23 21	37 51	246·1	2·69	1	9·1 9·2	·027	H.F.
Espin 546 ...	23 21	63 33	159·0	2·29	2	9·1 10·8	·741	W.B.
Ho. 489 ...	23 22	62 47	237·0	0·58	1	8·0 8·0	·027	H.F.
Dawes 2 CD	23 26	31 57	221·7	1·25	1	7·4 8·9	·027	H.F.
Hu. 999 ...	23 26	76 32	139·3	1·71	2	9·2 9·7	·850	W.B.
Σ 3020 ...	23 27	71 43	107·4	2·14	1	7·7 9·7	·821	W.B.
β 720 ...	23 29	59 10	177·0	0·48	1	6·0 6·0	·027	H.F.
OΣ 500 ...	23 33	46 4	333·2	0 65	2	6·1 7·0	·047	H.F.
Ho. 202 ...	23 34	50 1	138·9	2·19	1	8·3 11·8	·027	H.F.
			135·7	2·51	1	...	·660	W.B.
Hu. 792 ...	23 34	57 40	186·1	0·49	1	9·0 9·3	·027	H.F.
Ho. 203 ...	23 35	54 55	131·3	3·36	1	9·0 10·0	·027	H.F.
β 858 ...	23 37	57 56	252·9	0·69	2	7·7 8·2	·047	H.F.
AGC 14 ...	23 39	61 8	205·1	1·35	2	5·0 8·1	·354	W.B.
β 995 ...	23 43	43 40	233·5	0·75	2	6·5 8·5	·047	H.F.
Σ 3050 ...	23 55	56 46	216·5	2·56	1	6·0 6·0	·066	H.F.
			215·4	2·29	1	...	·660	W.B.
Holden 60	23 57	50 52	117·9	0·65	1	8·5 8·9	·027	H.F
Ho. 208 ...	23 57	59 46	229·0	0·66	1	8·0 10·0	·027	H.F.

New Double Stars. By the Rev. T. E. Espin, M.A.

During the spring, especially in the early part of the year, there have not been many fine nights; and when the sky has been clear, the definition has been usually very poor. The measures obtained in the case of faint comites are in several cases little more than approximations.

No.	B.D.	R.A. 1900. h m	Decl. 1900. ° ′	Position Angle. °	Distance. ″	Mags.		No. of Nights.	Date. 1909.	
705	+44,582	2 43·1	+44 59	225·9	8·26	8·5	11·7	3	·104	
706	+51,723	3 15·2	+51 18	126·9	2·60	12·5	13·2	3	·105	BC
				304·8	26·37	A=	8·6	3	·105	AB
707	+53,744	4 5·2	+53 29	152·9	8·87	8·3	13·2	2	·126	AB
				287·7	19·01	C=	12·6	2	·126	AC
708	+53,857	5 2 0	+53 31	68·1	3·52	9·2	12·0	2	·216	
709	+52,933	4·2	+52 13	228·2	1·94	9·0	9·2	5	·163	
710	+53,946	39·9	+53 43	173·6	2·65	9·2	12·0	1	·205	
711	+52,1026	53·0	+52 19	271·2	2·42	9·1	9·6	2	·136	
712	+53,1033	6 24·6	+53 19	249·1	7·60	9·1	9·6	1	·205	
713	+52,1171	7 0·4	+52 52	48·4	5·55	8·6	13·7	2	·135	
714	+53,1229	8 12·0	+53 35	194·2	5·97	9·1	12·5	3	·234	
715	+54,1279	9 2·5	+54 4	226·3	7·27	9·2	10·5	3	·301	
716	+52,1374	6·4	+51 58	293·2	7·52	8·5	10·5	2	·247	
717	+51,1501	16 3	+51 12	309·0	4·42	9·0	13·2	4	·279	
718	+52,1385	16·5	+52 2	26·5	7·90	9·2	11·5	2	·248	
719	+50,1662	30·3	+50 28	258·2	4·55	9·3	11·5	2	·277	
720	+50,1701	51·1	+50 42	90·8	3·07	9·3	12·7	2	·290	
721	+54,1373	10 18·7	+53 59	131·3	3·69	9·0	12·5	4	·277	AB
				285·5	33·88	C=	11·6	2	·278	AC
722	+53,1454	54·5	+53 9	107·0	8·42	9·1	10·7	2	·293	
723	+51,1704	11 44·7	+51 14	300·8	6·03	9·2	9·3	5	·295	
724	+51,1710	49·1	+51 6	227·0	3·12	9·0	11·3	3	·311	
725	+47,1933	12 5·0	+47 9	58·4	6·83	8·9	9·3	2	·341	
726	+54,1531	26·0	+54 25	173·4	9·64	9·1	11·0	3	·328	AB
				171·3	21·67	C=	12·2	3	·328	AC
727	+46,1810	35·5	+46 10	13·6	6·02	8·3	11·5	1	·350	
728	+51,1779	37·3	+51 41	329·5	6·42	9·3	13·7	2	·296	
729	+54,1546	39·3	+54 21	226·3	8·97	8·5	12·0	3	·341	
730	+51,1785	44·6	+51 30	65·3	3·37	9·1	10·5	2	·287	
731	+46,1824	46·0	+46 37	348·6	12·14	8·0	12·5	1	·350	
732	+49,2204	13 10·9	+49 10	79·0	3·30	9·0	9·1	2	·349	
733	+54,1599	17·2	+53 53	210·9	6·21	8·8	9·4	3	·322	

No.	B.D.	R.A. 1900.	Decl. 1900.	Position Angle.	Distance.	Mags.		No. of Nights.	Date. 1909.
		h m	° ′	°	″				
734	+52,1697	18·0	+51 54	163·5	7·59	9·1	9·4	2	·282
735	+50,2017	34·2	+50 41	284·2	3·55	9·5	11·0	2	·349
736	+52,1747	48·1	+52 6	268·2	9·53	8·6	11·9	2	·312
737	+53,1696	14 9·3	+52 58	301·7	3·78	10·2	10·6	3	·339
738	+53,1707	18·8	+52 51	311·0	6·52	8·6	11·8	3	·333
739	+52,1843	58·7	+51 59	155·3	2·50	9·2	9·6	2	·349
740	+54,1739	15 15·9	+53 54	39·2	3·42	8·9	9·4	2	·334
741	+53,1773	17·0	+53 7	230·2	8·64	8·5	10·5	2	·341
742	+54,1767	44·7	+53 56	85·3	3·10	9·0	9·2	2	·346
743	+54,1792	16 2·7	+54 42	6·4	7·02	9·0	12·1	3	·337

Notes.

707.—The measures of the distances of both *comites* are unsatisfactory.

720.—A difficult object from the faintness of the *comes*. Examined on four nights.

728.—*Comes* faint and difficult to measure.

729.—Distance doubtful.

730.—There is no star in the position of B.D. +51°,1785 as given by Argelander. This star agrees with his R.A., but lies 2′ N. of his place.

Observations of helium D_3 absorption in the neighbourhood of Sun-spots in 1908.

By Captain R. A. C. Daunt, D.S.O.

The following observations of D_3 absorption in the neighbourhood of sun-spots were made with the same instruments as in previous years, viz. 3-inch equatorial refractor and Thorp prism-grating spectroscope, 15,100 lines to the inch, the eyepiece usually employed being a Steinheil monocentric 20 mm, giving a power of 52.

There is little to add to the remarks made at the head of the tables in the paper on this subject last year, *Monthly Notices*, June 1908. The tables have been drawn out on the same plan, and the system of numbering the sun-spot groups is the same as previously.

The intermittent nature of the appearance of the dark D_3 absorption-line has again been noted; groups which showed D_3 absorption on some days did not do so on others.

As previously, the D_3 line had a broken, patchy, lumpy appearance in all cases under observation with one exception, viz. group No. 6491 on August 1st., when, in addition to the lumpy, thickened appearance of D_3 in rear of the group, the D_3 line of absorption showed as a fine narrow line running across the group; *vide The Observatory*, September 1908. This is the only occasion I have recorded an observation of D_3 as a fine narrow line. A double reversal of the D_3 line was recorded in the area between groups Nos. 6393 and 6396 on April 4th.

In every case of observation of the dark D_3 line the C line of hydrogen showed disturbance, and in every case was reversed. The most remarkable disturbance of the C line took place on April 4th., between groups Nos. 6393 and 6396, at the time when D_3 was doubly reversed. In most cases the dark hydrogen flocculi were well seen.

The percentage of sun-spots showing D_3 in absorption is slightly lower in 1908 than in 1907.

The groups 6490, 6491, visible at the end of July and the beginning of August, were the seats of considerable disturbance. In addition to the reversals of D_3 and the bright reversal of the C line, large dark flocculi were seen on the C line, extending all over the regions of disturbance, while D_1, D_2, and the *b* group were greatly twisted and distorted in the neighbourhood of the spots.

TABLE I.

Groups in which D_3 was observed as a dark line.

Greenwich No. of Group.	Type of Group.	Dates on which D_3 was observed as a dark line.	Behaviour of Hydrogen Line C.
**6338, 6339	IV_b, III	Jan. 4, 9	twisted and reversed
6350	I	,, 18	,, ,,
6356	IV_a	,, 29	lumpy and reversed
**6360	III	Feb. 4	lumpy, brilliant reversals
6364	IV	,, 9	lumpy and reversed
6366	III	,, 14, 15	distorted and reversed
6374	III, IV_c	,, 25, 27	lumpy and reversed, brilliant reversals on Feb. 27, D_3 very conspicuous
*6377	IV_b	Mar. 4	lumpy, brilliant reversals
6381	III	,, 11	distorted, brilliant reversals
6382	I, IV_b, I	,, 11, 12, 19, 20	,, ,, ,,
6383	II	,, 19, 20	distorted and reversed
6387, 6388	III	,, 19, 20	reversed
6389	IV_b	,, 31	bright reversals
6390	III, IV_b, II_a, IV_a	Apr. 6, 7, 11	,, ,,
6391	IV_b	,, 4	distorted and reversed
*6393, 6396	III_a, IV, III, IV_b	,, 4, 5, 6, 7, 9, 11, 12	great disturbance, brilliant reversals

TABLE I.—*continued.*

Greenwich No. of Group.	Type of Group.	Dates on which D_3 was observed as a dark line.	Behaviour of Hydrogen Line C.
6397	I	Apr. 4, 5	bright reversals
6392	II	,, 5, 6, 7, 9	,, ,,
6398	IV_b	,, 7	,, ,,
6403	I	,, 11	distorted and reversed
6405	I	,, 23	bright reversals
*6414	III, II	,, 25, 26, 27, May 1	brilliant reversals
6421	I	May 1	reversed
*6416	IV_a	,, 7	many reversals
*6424	IV_c, I	May 7	bright reversals
6425			
6432	I	,, 11	,, ,,
6436	IV_a	,, 13	many reversals
6463	I	June 28, 29	bright reversals
6478	III	July 18	pale reversals
6482	I	,, 21	bright reversals
6486	I	,, 21	reversed
6490	III_a, III_b, V	,, 30, Aug. 1, 2, 3, 5, 6	reversed, brilliant reversals, Aug. 12
*6491	IV_c, V, IV_e	Aug. 1, 2, 3, 5, 6, 11	brilliant reversals, great distortion, D_3 a fine line, Aug. 1
6494	III	,, 6, 11	reversed
6499	II	,, 14, 15, 16, 17	brilliant reversals
*6510	II, III	,, 27, 30, Sept. 1	distorted, bright reversals
*6511	IV_b	,, 30	reversed
**6518	I, III	,, 30, Sept. 1	lumpy and reversed
6549	I	Oct. 12	bright reversals
6564	III_a, V	Nov. 8, 9, 12	distorted, brilliant reversals
6565			
6568	I	,, 19	reversed
6575	III	Dec. 6	,,

An asterisk before a group number denotes that the group was seen a second time, and successive returns of a group are denoted by two, three, and four asterisks.

TABLE II.

List of Spot-groups in which the D_3 line was not observed.

Greenwich No.	Type.	Greenwich No.	Type.	Greenwich No.	Type.
6329	I	6406	IV	6501	I
6333	IV_b	6407	IV	6502	I
6334	I	6408	I	6503	I
*6335	IV_a	6409	I	6504	I
6336	I	6411	I	6507	I
6337	I	6412	I	6512	I
6341	I	6413	I	6513	I
6342	I	6418	IV_b	6516	IV
*6344	IV_a	*6419	IV_a	*6517	IV
6346	I	**6420	IV_a	*6535	I
6348	I	6422	I	6537	IV_b, IV_a
*6349	II_a, IV_b	6423	I	*6539	IV_b
6359	I	6427	I	6541	
*6361	I	6429	I	*6540	IV_a, IV_b
6367	I	*6430	IV, I	6543	I
*6368	I	6431	I	6547	IV, I
6363	I	*6464	IV_a, IV_b	6548	I
6370	I	6465	IV_a	6550	IV_a
6371	I	6466	I	6556	I
6372	IV_a, IV_b, IV	6468	I	***6558	IV_a
6375	I	6469	I	6559	IV_a
6376	III	6470	I	6561	I, III
6378	IV_b	6471	IV	6560	III
6379	IV, I	6472	IV	6562	
6385	IV_b	6480	I	6566	I
*6386	IV_a	*6481	I	6567	III_a
6394	II	6484	I	****6572	I
6395	I	6488	I.	6573	I
6399	I	*6489	IV_a	6574	I, IV_b
6401	IV_a, IV_b	6497	I, IV	*6577	IV_a
6402	I	6498	I	6578	I
6404	I	6500	I	6579	IV

TABLE III.

Showing the proportion of Spot-groups which showed D_3 as a dark line.

Month.	No. of Days of Observation.	Total No. of Groups observed.	No. of Groups in which D_3 dark.	Percentages.
January	5	15	4	26·6
February	11	15	4	26·6
March	12	10	7	70·0
April	17	22	10	45·4
May	4	13	6	46·1
June	3	4	1	25·0
July	7	14	4	28·5
August	12	26	7	27·0
September	1	—	—	—
October	9	11	1	10·0
November	6	9	3	33·3
December	1	5	1	20·0
				Percent. on the Totals
Totals	88	144	48	33·3

Aldershot:
1909 *April* 13.

[*Note added by the Rev. A. L. Cortie, S.J.*]

Captain Daunt has again courteously submitted his paper and his note-book of observations for my perusal in order that the opportunity may be afforded me of adding a note to the above tables. As in the observations of the reversal of D_3 made in 1907, so in those of 1908 the reversals have for the most part taken place in the earlier or disturbed periods of the life-histories of the spots. At the same time there is a fair percentage of round regular spots in Table I. in which the phenomenon has been noted. It must be remembered, however, that this type of spot was very prevalent in the year 1908, much more so than in 1907. In Table II., which contains the groups in which the phenomenon was absent, the spots were generally small or in the last stages of their life-histories. The larger groups in this table were round, regular spots of Type IV. Nevertheless, one group, 6480, though of short life showed considerable activity. In the life-histories of spot-groups the active stages are represented by Type I. when a few scattered dots appear amid bright condensed faculæ, Type II. when these scattered dots begin to coalesce into two main spots, and

Type III., the most active phase, when the area contained between these two main spots is filled with detached smaller spots, generally surrounded by considerable patches of penumbræ. This phase generally supervenes between 5 and 7 days after the birth of the spot (*Astrophysical Journal*, vol. xiii. p. 262), and it is noteworthy that the area between the two main spots of a typical group is that which visually shows the greatest disturbance. Both in the observations of 1907 (*Monthly Notices*, vol. lxviii., 8, p. 625) and in those of 1908 the seat of the dark reversals of D_3, and the accompanying bright reversals and distortions of H_a, was precisely in this area between the two main spots, or in the region following the leading spot, when that stage had been reached in the development of a group where the following spot of the group had been absorbed. Notable examples were the groups 6393, 6489, 6490, 6491, 6494, and 6564, in the observations of 1908. In his paper on "The Distribution of Eruptive Prominences on the Solar Disk" (*Astrophysical Journal*, vol. xxviii. p. 253), Mr. Philip Fox points out that the brilliant eruptions of calcium and hydrogen flocculi shown in spectroheliograms in the neighbourhood of spots also take their origin in these regions. Captain Daunt's notes contain several observations of dark flocculi on the H_a line in the same regions. The region therefore of the greatest activity in the development of a sun-spot group lies between the two main spots of the group. It is probably due to the swirling in of the photospheric matter, with the consequent disturbances in the upper flocculous and chromospheric levels, between the cooled, dark, raised masses of metallic vapours which are represented by the umbræ of the two main spots of the groups. The very lie of the detached small umbræ and penumbral masses between the two spots, which gradually arrange themselves into approximate parallelism with the Sun's equator, visually suggests the swirl.

In the column of percentages of Table III. a great increase is shown in the numbers between January and March. Though the activity of the spots, allowing for the imperfection of the record, increased so far as D_3 absorption effects were concerned, there was a general decline both in the number and areas of the spot-groups. But the diurnal range of the declination magnet increased in the same period. The coincidence may be merely fortuitous, but is worthy of record.

Stonyhurst College Observatory:
April 17, 1909.

Note on the Solar Constant and the Apparent Temperature of the Sun. By M. C. Féry, D.Sc.

(*Communicated by Sir David Gill, K.C.B., F.R.S.*)

The *Solar Constant* is the quantity of heat received by the Earth in calories per sq. cm. per minute, correction being made for the atmospheric absorption.

The *Apparent Temperature* of the Sun is that which a perfectly black body would have, which produced the same intensity of radiation, with the same apparent diameter as the Sun.

It is unnecessary to insist upon the importance of the determination of the solar constant; it is from the Sun that we derive, more or less directly, all the various forms of energy that we see transformed around us. Hence we have a large number of different types of actinometers which aim at measuring the solar constant or recording its variations. In principle they all contain a body exposed to the radiation, and which is termed the *receiver*, this body being covered with a substance of high absorbing power. Differences in detail exist in the mode of measuring the energy absorbed by the receiver. In those instruments which may be termed *calorimetric*, the rise of temperature of the receiver, of which the mass and specific heat are known, enables the energy received to be easily calculated (Pouillet, Violle, etc.).

In the more recent, so-called, *compensation* actinometers, the idea has been to balance the effect of the solar radiation falling on one of the junctions of a thermopile by an electric current, which imparts to the other junction a definitely known number of watts (Knut Ångström).

Measurement of the Solar Constant.

One of the greatest difficulties in this measurement lies in the evaluation of the atmospheric absorption. It is in fact to the doubt which exists as to the value of this correction that we may attribute the greater part of the enormous range (A = 1·5 to 4) obtained in the measurements. The general consensus of opinion at the present day is in favour of taking A as 2·4.

Measurement of the Solar Temperature.

Before the exact law of radiation was known, observers were content to extrapolate various formulæ for evaluating the temperature of the Sun. Terrestrial measurements made for determining the coefficients in these formulæ rarely dealt with temperatures exceeding 1000° C. It is not astonishing, therefore, that inexact formulæ extrapolated from these low temperatures gave rise to values varying between 1500° and several millions of degrees.

It is, however, the figures above the probable mean apparent

temperature (5360° C.) which are the most numerous in these early determinations. This remark also applies to high temperatures in general; platinum, for instance, has seen its melting-point lowered from 2000° C. to 1730° C. in a few years.

This exaggeration is due to the intensity of the physiological sensation caused by bodies at temperatures above 1400° C. The retinal sensation produced is also a function of the general illumination of the room occupied by the observer, as it depends upon the *aperture of the pupil*; it depends also largely upon the dimensions of the hot body, as its temperature, measured by the scale of Pouillet, appears lower as its size is reduced. Who would have imagined the temperature of carbon filaments to be as high as 1700° or 1800° C. before the measurements of le Chatelier?

Applications of Stefan's Law to Astronomy.

About 1880 Stefan enunciated for the first time the *exact* relation which exists between the temperature of a body and the energy which it radiates, and a few years later the law of the fourth power was theoretically demonstrated in the case of a black body by Boltzmann.

Wilson was the first who introduced the idea of applying the Stefan-Boltzmann law

$$Q = a\,(T^4 - t^4)$$

to the study of the apparent temperature of different points of the Sun's surface. Until then this investigation had only been made by *photometric measurements of luminosity* which showed a certain lack of precision, in common with all other physiological measurements. Wilson received the radiation of the Sun upon one of the junctions of a Boys radiomicrometer, and that from an electric furnace upon the other junction. By varying the opening of the furnace and its distance, the deflection could be reduced to zero, indicating the equality of the two intensities of radiation. This method has some analogy to that of Ångström, but should be still more rigorous, as it compares the sources of energy *in the same form.*

Wilson obtained 5286° as the mean temperature by direct measurement. The correction of 29 per cent. which he applied to this value, assuming a coefficient of zenith transmission of ·71, gave him 5773° C. as the temperature measured outside the limits of the atmosphere.

A value of from 7000° C. to 10,000° C. is, however, accepted for the mean temperature. Poynting has made the following remark on this subject:* "This [Wilson's] is no doubt too low a value. Either, then, Wilson's zenith transmission was less than 71 per cent., or Kurlbaum's constant is too small."†

* *Phil. Trans. Roy. Soc.*, 1903, vol. 202 A.

† This latter hypothesis of Poynting's was correct as I have shown. *Comptes Rendus*, 5 Avril 1909, t. cxlviii. p. 915.

Since this time I have applied the Stefan law to the measurement of the highest temperatures used in industry, and more than 700 instruments based on this principle are actually in use. They are composed in principle of a gilded mirror which concentrates the total radiation of the furnace upon the minute junction (1 to 2 mm. in diameter) of a thermocouple. A portable galvanometer graduated in millivolts and in temperatures is employed for the measurements.

M. Millochau and I have thought that an instrument of this kind, suitably modified, would easily permit of the study of different parts of the solar surface. The junction of the thermocouple has been still further reduced in size (·5 mm. diameter) and the focal length of the mirror increased to 1 metre, which gives a solar image of 8 mm. diameter.

A sector-shaped diaphragm permitted the deflections to be reduced in a known ratio. The instrument was calibrated upon an electric furnace and upon the crater of an arc.

More than 750 observations made by M. Millochau at different altitudes, from Meudon to the top of Mont Blanc, and at different zenith distances on the summit, have led to fixing the coefficient of zenith transmission at the latter station as ·91.

The temperature at the centre of the Sun's disc with this correction was found to be 5550° C. absolute, and the mean temperature 5360°.

This apparatus having been acquired by an Indian university, was completely restandardised at the National Physical Laboratory. The deflections were found to be exactly proportional to the fourth power of the absolute temperature between 1600° C. absolute and the temperature of the arc. Being directed at Teddington upon the Sun on a very clear and dry day, it gave as the mean of eight concordant determinations 5153° absolute at the centre of the Sun's disc.

The coefficient of zenith transmission at Teddington therefore on this day must have been $\left(\frac{5153}{5550}\right)^4 = ·74$, or the absorption 26 per cent.

In calculating the mean temperature of the Sun from the accepted solar constant of 2·4, and by the aid of the corrected Stefan constant ($\sigma = 6·3$),* we obtain

$$T_m^4 = \frac{2·4 \times \frac{4·16}{60}}{6·3 \times \tan^2 \frac{\phi}{2}} \qquad \text{whence } T_m = 5920°.$$

* C. Féry, *Comptes Rendus*, 5 Avril 1909. I have determined this constant by means of an actinometer provided with a perfectly absorbent receiver. Preliminary experiments had shown me that the platinum black employed by Kurlbaum only absorbed 82 per cent. of the radiation from a body at 100° C., which this author had employed as the source of radiation; he thus obtained a value of $\sigma = 5·32$ watts, which is too low by 18 per cent.

This temperature is certainly too high; it would give a dominant wave-length according to Wien's displacement law, $\lambda_m\theta = 2940$, of $\lambda_m = \cdot 496\,\mu$, which is in the blue region of the spectrum.*

Conversely, we can calculate the solar constant from the mean solar temperature which M. Millochau has obtained on Mont Blanc, viz. 5360°.

We thus find

$$A = 6\cdot 3 \times 5360^4 \times \tan^2 \frac{\phi}{2} = \cdot 1125,$$

or in small calories per minute

$$\frac{\cdot 1125 \times 60}{4\cdot 15} = 1\cdot 65.$$

These considerations appear to show that the accepted solar constant is too high. This result is doubtless due to an exaggeration of the atmospheric correction; it may also be partially attributed to the fact that existing actinometers are all covered with substances having a selective absorption (lamp black or platinum black).

It would be of importance to investigate the best form for an actinometer to obtain complete absorption, and to repeat the simultaneous measurements of T_m and A, with a pyrometric telescope and a perfectly absorbing actinometer.

* The mean apparent temperature of the Sun calculated by the displacement law would be $\frac{2940}{0\cdot 54} = 5440$ absolute, adopting the value $0\cdot 54\,\mu$ for λ_m as found by Langley.

Erratum in Mr. Knobel's paper on a Chinese Planisphere.

Page 438, line 5, *for* Mas *read* Mao.